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Investigation of PCM Method for Cathodic Protection of Pipelines

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ABSTRACT

One of the dangers of storing materials in storage tanks is the leakage of materials due to corrosion to the surrounding environment, which in addition to cause damage due to the loss of valuable material and environmental pollution, can lead to accidents. PCM method is one which is used for inspecting pipelines by electromagnetic method. Electromagnetic fields easily pass-through soil, water, asphalt, etc. Therefore, without drilling and through the ground, pipelines are inspected and monitored. By measuring the amount of induced alternating current in its strong magnetic sensors, it is able to detect the current amount in pipelines, the position of sacrificial anodes, the quality of coating, and the location of its defects. In this method, alternating current is used to inspect pipelines. By increasing the frequency of alternating current, the inductive effect of this method increases on foreign structures and adjacent metal structures. In this case, by using different frequencies as well as very low frequencies, they eliminate the impact of adjacent foreign structures on the inspection results.

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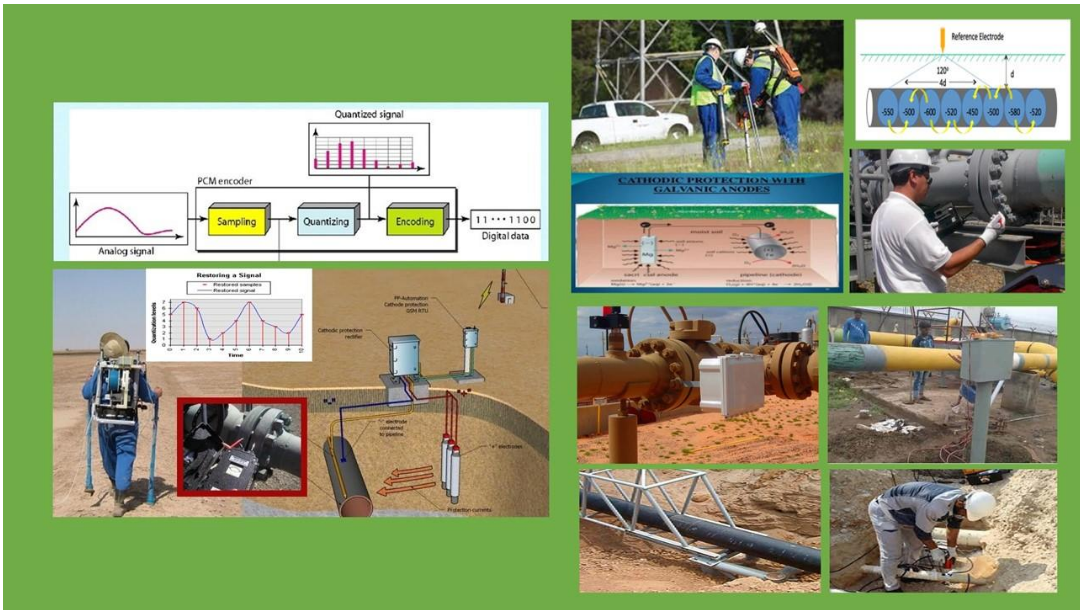
GRAPHICAL ABSTRACT



Introduction

Inspection and corrosion of pipelines that are not capable of pigmentation has been one of the issues in pipelines inspection. Direct evaluation of pipelines is one of the continuous methods of their optimization. External direct evaluation is a method based on NACE RP0502 standard. The basis of this method is relied on the fact that as long as the outer cover of the pipe is intact and perfectly separates the pipe from its surroundings, corrosion will not occur on the pipe's outer surface [1]. Now, if the cover is in a defective place, it is probably a good one for corrosion on the pipe's surface, which requires direct checks on the pipeline.

One of the dangers of storing materials in storage tanks is the leakage of materials due to corrosion to the surrounding environment, which in addition to cause damage due to the loss of valuable material and environmental pollution, can lead to accidents. Corrosion is the main phenomenon of degradation in carbon steel sheets of tank floors, which can occur on the product side (i.e. the internal corrosion) or on the soil side (i.e. the external corrosion). The internal corrosion can occur as a reduction in local or general thickness [2]. Factors affecting internal corrosion include the corrosive properties of stored product, the working temperature of the tank, the equipment of steam coil, and the presence of water in the bottom of storage tanks. The external corrosion is observed as a decrease in local thickness. Factors affecting external corrosion include soil type, bed type, water drainage system, cathodic protection, tank floor design, and tank operating temperature. Due to the high rate of corrosion in the soil for various corrosion mechanisms in most cases, the fluid leaks from the bottom of the tanks to the environment. Hence, the inspection of tank floor sheets is always done more carefully and sensitively [3]. Prior to 1988, it was conducted using the manual ultrasonic method and with a grid pattern, which was time-wasting due to the process nature. To improve his inspection strategy in 1988, Sanderson introduced the Magnetic Flux Leakage (MFL) method as an effective and rapid technique in which, by inducing a magnetic field into a sheet, a magnetic field leakage signal from a defect was provided by an array of non-contact magnetic sensors as being received and analyzed, but since the received MFL signals were related more to the volume of metal lost than to the cavity depth, the results of the MFL alone cannot be sufficient to interpret and comment. To investigate the defect depth, Sanderson used the manual UT method as a complementary technique, which is still used today as a test guide for tank floor sheets. Accordingly, in initial step, MFL inspection is performed to determine the suspicious areas, and then with the aid of manual UT test, the obtained results are checked and the remaining thickness is measured to determine the maintenance strategy [4].

Diagnosis

Experience has shown that many cathodic protection systems can fail to perfectly protect the structure due to design defects, incorrect equipment selection, or improper installation (Figure 1). Troubleshooting of these systems requires deep experience and technical performing knowledge of cathodic protection systems in order to find the essential solutions to eliminate defects and achieve the necessary protection potential in addition to detect faults (Figure 2) [5].

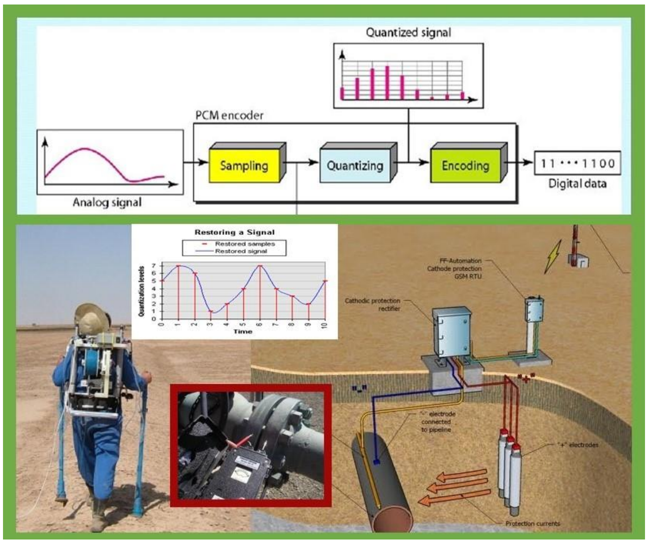


Figure 1. Pipeline Threat Assessment, PCM Method

Figure 2. Technical Inspection of PCM Method

Repair and maintenance

Timely maintenance and repair of cathodic protection systems can increase the life of equipment in addition to prevent poor performance and premature failure of these systems [6].

Cover repair

- ✓ First, the coating is evaluated by one of the conventional methods for coating evaluation, such as PCM, DCVG or ACVG, and defective points are identified for further inspection and repair [7].
- ✓ PCM or pipeline flow mapping is one of the most accurate methods of assessing pipeline coverage.
- ✓ This method is capable to detect defects in the cover of buried pipes in densely populated areas, forks, under asphalt, and roads with high spatial accuracy.
- ✓ The red dots on the maps indicate a sharp drop in flow from the pipeline, and experienced obstructive experts are able to detect all types of defects and separation of coatings based on the amount and severity of flow drop.
- ✓ After determining the location of defects and drilling, it is time to repair the cover. Deterrent experts, considering the cause of the defects and the previous type of coating, propose the specifications of the repair coating and supervise the process of its preparation and application.
- ✓ The coating repair process is a specialized process that includes these steps: removal of defective coating, surface preparation, application of the initial and middle layer, application of the final coating, and performing the quality assessment tests [8].

Internal rotation inspection system

This system is one of the advanced inspection methods. This technique, which operates on the basis of ultrasonic waves, examines the reduction of thickness, pitting corrosion, and uniform corrosion in the walls of pipes and tubes by sending a probe into the tube(s) [9]. In some circumstances such as boilers, heat exchangers, where, in some cases, it is not possible to inspect the tube surface from external surfaces, inspection can be done by sending a probe from inside the tube. The general principles of the method are to send ultrasonic waves into the tube and receive the reaction of these waves with the tube wall. Because the outer surface (OD) and inner (ID) of the tube both respond to these waves, this method is able to distinguish between corrosion on the inner and outer surfaces of tubes. In this method, the tube is filled with water to provide a wave bed. Using mirrors to reflect waves and the ability to rotate the probe in this way allows 360-degree examination inside the tube (Figure 3) [10].

Figure 3. Integrated Cathodic Protection (ICP) Surveying with an Autonomous Underwater Vehicle

As the probe advances into the tube and rotates, the entire surface of the tube can be examined and tested. The defect points can be traced in comparison with pipe length and angle, as well. Unlike MFL, which is used merely for magnetic metals, this method is applicable for all groups of ferrous and non-ferrous metals and supports a wide range of inner diameters of pipes and tubes. The inspection methods for burial pipe coatings in accordance with international standards and NACE SP 0502 and NACE SP 0109 are mentioned as follow: Measurement of coating electrical resistance, DC voltage gradient or DCVG, point-to-point measurement of potential of the CIPS structure, coating inspection, Pearson method, C-scan coverage, modern methods of measuring AC current damping, and flow map by PCM method. PCM method is one of the modern techniques of quality inspection of pipeline cover [11]. The basis of this method is relied on the use of alternating current and following the direction and amount of it inside the pipelines. The use of alternating current with different frequencies enables the PCM device to detect static and dynamic current interference in pipelines in intricate environments and complexes. Of course, this device can be further used in the inspection of intercity and national pipelines. In other words, the capabilities of the PCM device are far greater than the scan-C device [12]. Based on the available practical results, the inspection results of pipelines in urban areas with the aid of scan-C device have a significant error due to being single frequency, inability to detect interference, and other cases. Therefore, it cannot be used in gas distribution areas as an effective tool to inspect pipelines. As the frequency of alternating current increases, its inductive impact increases on foreign structures and metal structures adjacent to pipelines. The PCM device is able to eliminate the impact of adjacent foreign structures on the inspection results by using different frequencies as well as very low frequencies. The use of some methods such as DCVG and CIPS, which are based on the cathodic protection system, also is practically impossible and limited due to the inability to detect interference, the need for a cathodic protection system, the need for electrical insulation of pipes from other structures and earthing systems, the impossibility of piping, the accuracy, and inefficiency of these methods in asphalt and concrete environments [13]. Due to the presence of the pipe finder module in the PCM device and likewise, the internal GPS in newer models, the possibility of pipe tracking, recording the exact coordinates of E, N, the possibility of reading data from soil, concrete and asphalt, the possibility of eliminating interference with the help of very high frequencies 8 kHz to very low 4 Hz, the shortcomings of other methods inside the complexes are well fixed and this modern inspection technique with very high efficiency, excellent accuracy, very low address even at burial depths higher than 5 meters, the possibility of inspection, and evaluation of conditions provided coverage [14].

Things that can be done by this method are as follow:

- ✓ Inspect the burial pipe cover by measuring the leakage current as well as measuring the AC voltage gradient.
- ✓ Possibility to find pipes and determine the direction of pipe movement even in the buried paths under asphalt and concrete.
- ✓ Detect the location of wasted currents and collisions with other structures.
- ✓ Determine the direction of cables, especially cathodic protection cables.
- ✓ Locate the defect with exact coordinates E and N [15].
- ✓ Determine the defect severity with the aid of calculations based on ECDA method.

Table 1. Limitations and benefits of other methods

Limitations	Advantages	Method name
Is dependent on the operator. Requires a cathodic system. Requires an interpreter. Requires 3 operators and equipment. Is dependent on soil resistance. Needs for experience-based analysis. Inefficiency in asphalt and concrete. Inefficiency in complexes and intersecting pipelines.	Locate the defect. Determine the defect severity. Determine the fault time. Determine the anodic-cathodic defect. No need to access the pipe. Is suitable for all coatings except three layers. Determines small defects.	DCVG
Lack of accurate fault diagnosis alone. Requires a cathodic system. Requires an interpreter. Requires 3 operators and equipment. Need for experience-based analysis. Need for accessing the pipe. Inefficiency in asphalt and concrete. Inefficiency in complexes and intersecting pipelines.	Locates the defect. Determines the anodic-cathodic defect. Is suitable for all coatings. Determines the health of the cathode system on a point-to-point basis. Determines the anodic-cathodic defect	CIPS
Possibility of interference. Inefficiency in very humid environments.	Locates the defect. Determines the severity of the defect. Determines the fault time. Determines the anodic-cathodic defect. Determines small defects.	C-Scan
	Is suitable for very small defects less than 600 mm2 and without affecting the cathodic protection system. Is suitable for large defects and defects affecting the cathodic protection system. Is applicable for points and defects based on the experience of the operator who is able to prove it. Is suitable for close pipelines and complexes without interference.	PCM+

How the device works

The above device is designed and manufactured for the purpose of checking the cover for underground pipes, and its main difference with similar old devices is in the way of using electricity [16]. In older devices, high frequency AC current (usually 750 Hz) is used, which significantly reduces the signal sent by the enamel in the presence of a defect in the line cover, but in many cases, the defects of the pipe is evident due to a large error. The drop of this signal along the pipeline is not exactly detectable. However, in PCM + device, due to the use of low frequency AC current (similar to DC current), it does not have the above-mentioned errors and gives a more accurate analysis of the line coverage status to the user. The PCM+ device, given the capabilities and data it provides after the test, helps to detect coating defects and possible corrosion from the very beginning, thus increasing the service life of the pipes during the maintenance period. In this regard, it should be noted that due to the movement of alternating current in pipelines, only a variable magnetic field is created [17]. Therefore, no electromagnetic waves are generated, and therefore radio receivers do not receive any signal from the pipelines in this regard. In this method, by using sensitive sensors, the magnetic field caused by AC current passes through the tube edges and is measured (Figure 4). Whenever the body of an electric conductor is in a variable magnetic field, an alternating current is generated in it [18]. For instance, the passage of alternating current through the primary winding of transformers creates a variable magnetic field around it. The secondary winding located in this field will be inductively alternating current. The same is true for pipeline magnetic field sensors. There is a direct relationship between the intensity of the induced current and the intensity of the magnetic field. The stronger the magnetic field, the greater the induced current. Therefore, by measuring the amount of current induced in the magnetometer sensor, the intensity of the magnetic field is measured. Magnetic field strength changes measured along the pipeline identify areas of magnetic field leakage which are the same areas of coating defect [19]. Therefore, considering that the basis of this method is to measure the magnetic field of pipelines, and thus there is no need for full contact of the sensor with the ground. In addition, the magnetic field easily passes through soil, water, concrete, and asphalt, so it is easy to measure the magnetic field on them. The transmitter sends signals close to the DC current into the tube and the receiver detects the resulting magnetic field from the soil surface.

Figure 4. Cathodic Protection Design Services

The receiver has a magnetometer sensor and by pressing the corresponding button on the receiver, the sensor is activated and begins to map the flow of pipelines. Inductor inductance resistance increases with maximizing AC frequency and capacitor inductance resistance decreases, as well [20]. By using inductors and capacitors, it is possible to create a current that intensifies the current in the electronic circuit, and thus the weak magnetic field of the pipeline can be seen by the magnetometer sensor [21].

Dcvg, Direct Current Voltage Gradient

It is a method for evaluating the coating quality according to the NACE SP 0502 standard, assuming the existence of a cathodic protection system, which is done today in two models, as digital and analog [22].

A) Operating method

Consider a pipeline that is under protection, but is connected to the ground on part of the route due to a breakdown. Evidently, the protection current enters the pipe from this place and through the ground. The entry of current through the ground into the pipe, taking into account the soil resistance of the site, causes a voltage drop across the ground around the fault site, which results in circular concentrations but with different potentials. The larger the coating defect, the greater the voltage gradient or its slope. On the other hand, the value of the voltage slope is a function of soil's specific resistance at the fault location [23].

B) Components of analog DCVG device

- ✓ A zero-hand voltmeter in the middle.
- ✓ An adjustable current INTERRUPTER number compatible with a voltmeter.
- ✓ Two copper rod/copper sulfate electrodes fitted with a voltmeter.

C) Digital DCVG device components:

- ✓ Cathodic system-specific data logger with DCVG module.
- ✓ INTERRUPTER adjustable flow and compatible with Vditlogger.
- ✓ Two copper rod/copper sulfate electrodes fitted to the data logger.

D) DCVG fault detection method

The most accurate method available for determining the types of DCVG coating failures is the pipeline technique. Regardless of the surface (soil, asphalt, concrete, and even water), the pipeline is inspected or what type of coating is used. This device detects small toe defects of the tip with a difference of a few centimeters on a pipe that is buried at a depth of one to two meters.

E) Features

- ✓ Determining the center of failure of the coating with an error of 15 cm.
- ✓ Inspecting complex pipeline networks (available in petrochemicals).
- ✓ Determining the approximate severity of damage to each wound.
- ✓ Determining corrosion behavior (direction of flow motion).
- ✓ Checking the performance of CASING and INSULATING FLANGE.
- ✓ Identifying faulty posttests.

Cips, Close Interval Potential Survey

Usually, the pipe's voltage is measured relative to the soil in gas or water transmission pipelines at intervals of one kilometer, and in the case of feed at intervals of one kilometer or five hundred meters, and in distribution lines at distances of 250 m. However, sometimes it is essential to check the quality of the coating or to determine the weaknesses between the two measuring points, the method of close distances is used, in other words, by using this technique; we can ensure the proper protection of a certain range. This method is frequently repeated one month after burying the pipe, and then every five years. It is better to use a GPS (satellite positioning device) for determining the position. To record ON and OFF voltages, it is better to use a data logger (voltmeter with memory). For simultaneous disconnection and connection of rectifiers, the CICS device should be used and it can perform ON and OFF operation simultaneously via satellite [24].

A) Advantages

- ✓ Obtain the perfect ON and OFF voltage profile of the pipe relative to the soil.
- ✓ Record ON and OFF values in the computer memory according to the spatial location of the measuring points and the possibility of printing, as well as estimating the current and future protection status.
- ✓ Identify coverage weaknesses.
- ✓ Recognize possible interfering voltages.

B) Limitations

- ✓ It is necessary to walk the pipeline length.
- ✓ At least three operators are required.
- ✓ Measurements are not easily possible in places such as asphalt roads, paved roads and rivers.
- ✓ Areas with severe corrosion are not recognizable.
- ✓ Places where the cover is detached from the pipe are not recognizable.

- ✓ The location of disconnecting and reconnecting the transformers at the same time is not easily done correctly and sometimes it is not practical [25].

Measurement of electrical resistance of coating, measurement of current damping, cathodic protection potential along pipelines, evaluation of coating quality using potential slope method, evaluation of pipeline coating quality by measurement of soil surface potential measurement, quality of pipeline potential, Pearson method, inspection of pipeline cover by C-Scan method, inspection of pipelines by means of electric current mapping of pipelines, and PCM method are modern techniques of corrosion inspection of pipelines buried in the soil [26].

Conclusion

The main reason for the separation of the coating from the tube surface is the pH increase of the electrolyte at the interface between coating and tube, which is formed by the following reactions. The rate of this pH increase at the interface between the tube and the end of separation site is very high and depends on factors such as the rate of cathodic reactions, the rate of penetration of the cations, the shape of the isolated area, and other reactions. The PCM+ device includes a portable transmitter and a handheld receiver. The transmitter sends a special signal to the pipeline and the receiver can detect this signal, the position, the depth of the pipe, the amount of leakage current along the pipe along with the direction of the measured current, and the range of coverage defects. Using the A-Frame, the position and severity of defects can be further determined. Powerful features of PCM + include the ability to automatically evaluate signal attenuation (ASA), current orientation (ACD), and ground compliance compensation (AGC). This feature allows PCM + to operate the pipeline exactly even in areas where there is a contact with other metal structures, electrical interference, or structural compaction.

References

[1] P. Blanc, B. Gschwind, M. Lefevre, L. Wald, The HelioClim project: Surface solar irradiance data for climate applications. *Remote Sens.*, 3 (2011) 343–361.

[2] T. Huld, R. Muller, A. Gambardella, A new solar radiation database for estimating PV performance in Europe and Africa. *Sol. Energy*, 86 (2012) 1803–1815.

[3] M. Suri, T. Huld, E. Dunlop, H. Ossenbrink, Potential of solar electricity generation in the European Union member states and candidate countries. *Sol. Energy*, 81 (2007) 1295–1305.

[4] J. Remund, S. Kunz, METEONORM: Global Meteorological Database for Solar Energy and Applied Climatology; Meteotest: Bern, Switzerland, 1997.

[5] J. Antonanzas, N. Osorio, R. Escobar, R. Urraca, F.J. Martinez-de-Pison, F. Antonanzas-Torres, Review of photovoltaic power forecasting. *Sol. Energy*, 136 (2016) 78–111.

[6] K.B. Debnath, M. Mourshed, Forecasting methods in energy planning models. *Renew. Sustain. Energy Rev.*, 88 (2018) 297–325.

[7] F. Almonacid, P. Pérez-Higueras, E.F. Fernández, L. Hontoria, A methodology based on dynamic artificial neural network for short-term forecasting of the power output of a PV generator. *Energy Convers. Manag.*, 85 (2014) 389–398.

[8] D. Anagnostos, T. Schmidt, S. Cavadias, D. Soudris, J. Poortmans, F. Catthoor, A method for detailed, short-term energy yield forecasting of photovoltaic installations. *Renew. Energy*, 130 (2018) 122–129.

[9] A. Bugała, M. Zaborowicz, P. Boniecki, D. Janczak, K. Koszela, W. Czekała, A. Lewicki, Short-term forecast of generation of electric energy in photovoltaic systems. *Renew. Sustain. Energy Rev.*, 81 (2018) 306–312.

[10] S. Sobri, S. Koohi-Kamalia, N.A. Rahima, Solar photovoltaic generation forecasting

methods: A review. *Energy Convers. Manag*. 156 (2018) 459–497.
[11] M. Cococcioni, P. Ducange, B. Lazzerini, F. Marcelloni, A Pareto-based multi-objective evolutionary approach to the identification of Mamdani fuzzy systems. *Soft Comput*., 11 (2007) 1013–1031.
[12] A. Mellit, A.M. Pavan, A 24-h forecast of solar irradiance using artificial neural network: Application for performance prediction of a grid-connected PV plant at Trieste, *Italy. Sol. Energy*, 84 (2010) 807–821.
[13] C. Monteiro, L.A. Fernandez-Jimenez, I. Ramirez-Rosado, A. Muñoz-Jimenez, L.P. Santillan, Short-term forecasting models for photovoltaic plants: Analytical versus soft-computing techniques. *Math. Probl. Eng*., 2013 (2013) 767284.
[14] Y.K. Wu, C.R. Chen, H.A. Rahman, A novel hybrid model for short-term forecasting in PV power generation, *Int. J. Photoenergy,* 2014 (2014) 569249.
[15] J. Zeng, W. Qiao, Short-term solar power prediction using a support vector machine. *Renew. Energy*, 52 (2013) 118–127.
[16] C. Cecati, J. Kolbusz, P. Rózycki, P. Siano, B.M. Wilamowski, A novel RBF training algorithm for short-term electric load forecasting and comparative studies. *IEEE Trans. Ind. Electron*., 62 (2015) 6519–6529.
[17] S. Yu, K. Wang, Y.M. Wei, A hybrid self-adaptive particle swarm optimization–genetic algorithm–radial basis function model for annual electricity demand prediction. *Energy Convers. Manag*., 91 (2015) 176–185.
[18] H.T. Pedro, C.F. Coimbra, Assessment of forecasting techniques for solar power production with no exogenous inputs. *Sol. Energy*, 86 (2012) 2017–2028.
[19] J. Liu, W. Fang, X. Zhang, C. Yang, An improved photovoltaic power forecasting model with the assistance of aerosol index data. *IEEE Trans. Sustain. Energy*, 6 (2015) 434–442.
[20] M.P. Almeida, O. Perpiñán, L. Narvarte, PV power forecast using a nonparametric PV model. *Sol. Energy*, 115 (2015) 354–368
[21] F.M. Camilo, R. Castro, M.E. Almeida, V.F. Pires, Economic assessment of residential PV systems with self-consumption and storage in Portugal. *Sol. Energy*, 150 (2017) 353–362.
[22] A. Núñez-Reyes, D. Marcos Rodríguez, C. Bordons Alba, M.A. Ridao Carlini, Optimal scheduling of grid-connected PV plants with energy storage for integration in the electricity market. *Sol. Energy*, 144 (2017) 502–516.
[23] K. Lo Han, P. Shirzadi, P. Vaziri, A. Johnson, Investigating the Effects of Government Oil Policies on the Iranian Economy, *Journal of Engineering in Industrial Research*, 3(2022), 168-173.
[24] P. Vaziri, P. Shirzadi, K. L. Han, A. Johnson, Investigating the Possibility of Modifying Water Management Engineering, *Journal of Engineering in Industrial Research*, 3 (2022) 174-181
[25] A. Samimi, A. Bozorgian, M. Samimi, An Analysis of Risk Management in Financial Markets and Its Effects, *Journal of Engineering in Industrial Research*, 3 (2022) 1-7.
[26] F. Mohammadkhani Orouji; Z. Saeid, Role of Oil and Gas Industry in International Security, *Journal of Engineering in Industrial Research*, 3 (2022) 8-16.

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