A machine learning Technique framework to maximize consumption of Natural gas in the network grid using online gas chromatograph *

Ahmed I. ElSeddawy, Amr Mokhless Arida

Assoc. Prof. Information systems department, Arab Academy For Science And Technology -AASTMT, Smart Village, Giza, Egypt;
College of Engineering and Technology, Arab Academy For Science And Technology -AASTMT, Smart Village, Giza, Egypt.
Email: Ahmed.Bahgat@aast.edu
Amrmokhless@gmail.com

ABSTRACT

Energy conservation is paramount importance for natural gas especially considering high oil prices as any wastage of energy leads to increased production cost. Several tools are available to assess a design of natural gas consumption this study about a technique framework to reduce natural gas Consumption. The purpose of this study to distribute the production of natural gas for various consumers, Each with certain chemical composition and properties of natural gas which satisfy the customer demand and reduce the consumption of the natural gas at the network grid. The Using Machine learning (ML) to handle the input data for more efficiently with different algorithms with natural gas maneuver reducing gas consumption and maximize daily production.

Keywords : The natural gas network grid , maximization of natural gas , Online Gas Chromatograph, Machine Learning, BTU, SCADA System, proposed framework, Maneuver Scenario.

1 Introduction

Hydrocarbons are a term that refers to natural gas, crude oil, and coal. Hydrocarbons often known as petroleum compounds made up of the elements hydrogen and carbon as well as impurities. The fewer carbon molecules to be found in the gaseous phase. Natural gas is made up of hydrocarbons that remain in the gas phase at 20°c , atmospheric pressure and a varied percentage of two major constituents.
Dry Lean Natural gas with low BTU and high methane content while Rich wet gas high BTU that contains less than 95% methane and more than 5% hydrocarbon molecules.

Proposing and establishing a frame network to adapt natural gas consumption in network grid using online gas chromatograph providing appropriate solutions for operating and controlling natural gas flow from the production wells to the end user. By using a machine learningsoftware to analysis the collected data and propose suitable network route for achiving the customers demand with the highest efficiency and the lowest BTU value for maximizie natural gas consupation. [1], [2], [3]

2 Controlling and operation of the Natural Gas Distribution Network Grid in Egypt

The natural gas pipeline network grid, with highly integrated transmission and distribution grid, includes producing wells, collection, transmission, distribution pipelines, compressor stations, and storage facilities. To meet the rising gas demand and connect customers with production centers, gas pipelines are being extended, serving as a critical link between gas producers and final consumers. The major goal of the natural gas grid is to move natural gas from the main production wells (on-shore and off-shore) to various customers in order to optimize natural gas consumption.

2.1 Natural Gas Network Grid Flow Chart

- The transportation services for the network grid shall be provided with pipelines includes compressor stations, pressure reduction stations, gas measurement plants, as well as auxiliary equipment required for gas transportation and dispatching. [7], [8], [9]

- A pressure reduction station is where natural gas is delivered to customers after filtering, metering, and reducing pressure to supply the natural gas with specific pressure and quantity and temperature to serves a variety of clients (domestic, industrial, electricity power stations, vehicles gas stations and household consumers) . [10][11][12]
- The sectionalizing valve rooms are all over the gas grid each 15-20 km for maintenance and operation of the pipelines network.
- Measuring stations should be exist at all Entry Points ,Shippers and local Gas Producers and Also the Custody Transfer measurement Exit Points where the pipeline grid delivers gas at either the Final Consumers or at the inlet of every local distribution network by using Various types of gas metering systems. [13], [14]

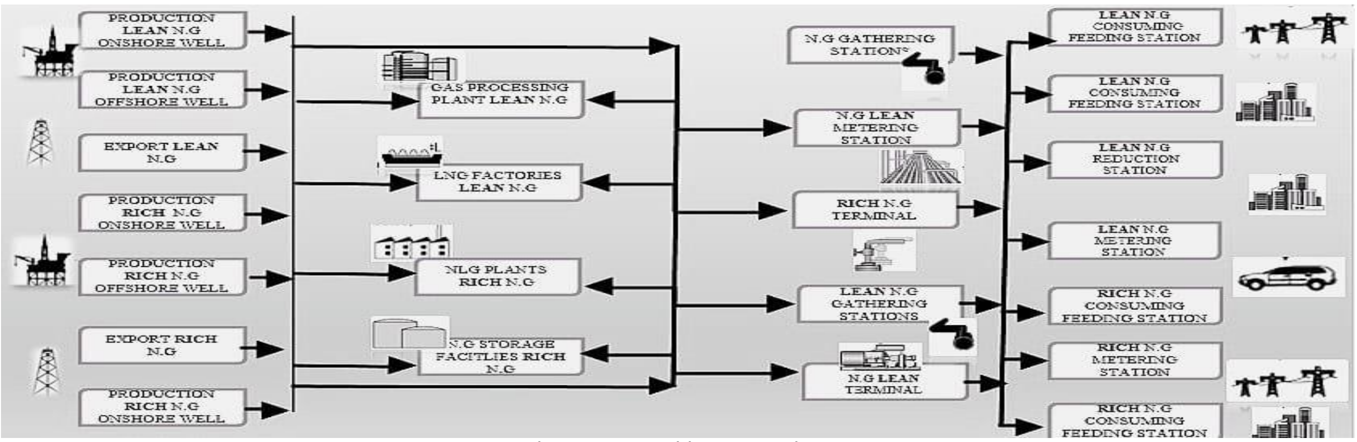

Figure 4 N.G Grid Framework

2.2 The Supervisory Control and Data Acquisition System (SCADA)

SCADA system is a technologically highly advanced integrated system bringing the fields' status and data to the field of vision while masterminding co-ordination and control of gas transmission & distribution via an advanced bundle of software applications making remote processes visible to everyone from control room operators to contingency management team. It provides a 24-hour uninterrupted service, assures the network's operation in terms of security efficiency Collecting Real Time , Reading for Natural Gas Flow Rates, Pressures, Temperatures and Calorific Values and Recording Historical Data Performing control command such as valve close/open command using remote terminal units located at remote sites Issuing alarms related to operation, equipment and telecommunication systems.

3 A MANEUVER SCENARIO WITH FEASABILITY STUDY USING ONLINE GAS CHROMATOGRAPH

3.1 Proposed Maneuver Scenario Route from Gas Production Field to UGD Using the Proposed Online Gas Chromatograph

A scenario aim for describing and explaining the effectiveness of the proposed frame work for maximization the consumption of natural gas by online gas chromatograph in the network gas grid.
The Existing Natural Gas Network Grid with gas production plants 1-Elwastany plant , 2-Edco produce a large quantities of natural gas tosupply Damietta electric power station and and Gas Derivatives Company

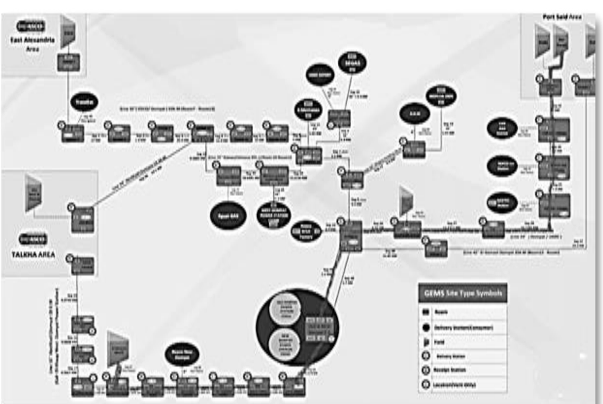
Figure 3 Installed O.G.C On production Points on N.G Grid

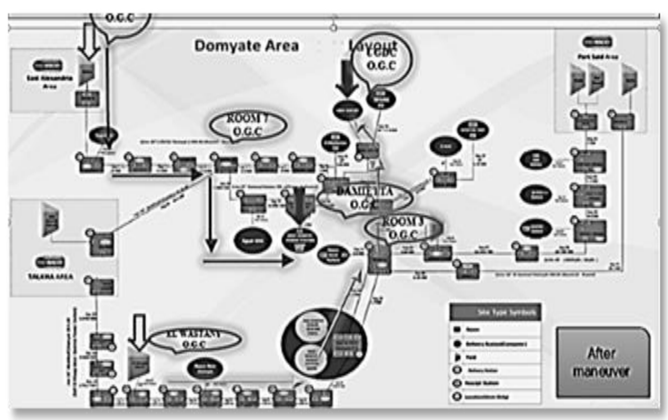

Figure 4 O.G.C terminal gas after maneuver scenarios

Step 1 : Installation an Online Gas Chromatograph at Significant Terminal Points (Elwastany , Edco) gas production plants and on sectional valves rooms and gathering points and at Consumer pressure reduction & metering gas Gas Derivatives Company factoriesas shown in fig 4 .

Step 2: Typically the provided reports by an online chromatograph used to determine the composition, heating value, and relative density of a natural gas sample

The following reports represents an information Results and analysis from Installation of Online Gas Chromatograph at Significant Terminal Points with results shown in fig 5 Elwastany gas plant produce a large quantities of rich natural gas to supply electric power station While in another situation Edco gas production plant produce lean natural gas to supply Gas Derivatives Company as shown in fig 6 .

.

BTU ANALYZER
Test time: mar .2021 18:11 calibration #:1
Test #:20 stream#:1 location no. WASTANY

	standatrd/dry analysis				saturated /wet analysis		
	MOLE%	BTU*	R.DEN.*	GPM**	MOLE%	BTU?*	R.DEN.
METH	95	962	0.53	0	93.4	945	0.52
ETHA	2.42	42.92	0.03	0.65	2.38	42.2	0.02
PROF	0.67	16.83	0.01	0.18	0.66	16.5	0.01
I-BUT	0.16	5.21	0	0.05	0.16	5.12	0
N-BU	0.13	5.37	0	0.04	0.13	4.29	0
I-PEN	0.05	2.03	0	0.02	0.05	1.99	0
N-PEI	0.02	0.93	0	0.01	0.02	0.91	0
(C6+)	0.08	3.99	0	0.03	0.08	3.92	0
MIST	0	0	0	0	1.74	0.88	0.01
NITR	0.37	0	0	0	0.37	0	0
(CO2	1.07	0	0.02	0	1.05	0	0.02
TOTA	100	1039	0.59	0.99	100	1021	0.59

UNCORRECTED FOR COMPRESSIBILTY AT 60 60ºF & 14.73PSIA
** LIQUID VOLUME REPORTED AT 60ºF

		STANDARD /DRY ANALY		SATURATED /WET ANALYSIS	
MOLAR MASS	=	17.1		17.2	
RELATIVE DENIS	=	0.59		0.59	
COMPRESSIBILI	=	1		1	
HEATING VALUE	=	####	Btu\lb	####	Btu\lb
HEATING VALUE	=	1041	Btu\CF	1024	Btu\CF
ABSOLUTE GAS	=	45.4	Btu\1000CF	45.4	Btu\1000CF
UNNORMALIZED	=	100			

LAST CALIBRATED WITH CAGAS OF 1050.3 BTU/CF MAR10.99 15:31
C6+ LAST UPDATE: MAR.02 9814:11
C6+ BTU/CF 5065.8,C6+ MOL.WT.92.00

Figure 5 Elwastany Plant Rich Gas Analysis By O.G.C

BTU ANALYZER
Test time: mar .2021 18:11 calibration #:3
Test #:165 stream#:1 location no.NODOCO 1

	standatrd/dry analysis				saturated /wet analysis		
	MOLE%	BTU*	R.DEN.*	GPM**	MOLE%	BTU?*	R.DE
METI	90	712	0.43	0	89.4	645	0.52
ETHA	5.32	32.92	0.02	0.45	2.56	32.2	0.02
PROF	0.97	10.83	0.02	0.17	0.96	15.5	0.01
I-BUT	0.86	5.21	0	0.03	0.66	4.18	0
N-BU	0.23	2.16	0	0.04	0.13	4.29	0
I-PEN	0.03	1.15	0	0.02	0.16	3.99	0
N-PEI	0.05	0.93	0	0.01	0.02	1.91	0
(C6+)	0.07	2.11	0	0.03	0.08	2.92	0
MIST	0	0	0	0	2.99	1.88	0.01
NITR	0.37	0	0	0	0.97	0	0
(CO2	2.08	0	0.01	0	2.08	0	0.02
TOTA	100	767.3	0.49	0.75	100	712	0.59

UNCORRECTED FOR COMPRESSIBILTY AT 60 60ºF & 14.73PSIA
** LIQUID VOLUME REPORTED AT 60ºF

		STANDARD /DRY ANALY		SATURATED /WET ANALYSIS	
MOLAR MASS	=	17.1		17.2	
RELATIVE DENIS	=	0.59		0.59	
COMPRESSIBILI	=	1		1	
HEATING VALUE	=	####	Btu\lb	####	Btu\lb
HEATING VALUE	=	1041	Btu\CF	1024	Btu\CF
ABSOLUTE GAS	=	45.4	Btu\1000CF	45.4	Btu\1000CF
UNNORMALIZED	=	100			

LAST CALIBRATED WITH CAGAS OF 1050.3 BTU/CF JAN 10.99 16:31
C6+ LAST UPDATE: MAR.02 9814:11
C6+ BTU/CF 5065.8,C6+ MOL.WT.92.00

Figure 6 Edco plant lean Gas Analysis By O.G.C

Proposing a new maneuver scenarios route from elwastany natural production gas field to gas derivatives company and Edco natural production gas field to power station.

Typical Analysis Report after Maneuver representating information that is typically provided by an online chromatograph used to determine the composition, heating value, and relative density of a natural gas sample before the maneuver scenario at Gas Derivatives Company & power stations fig(8,9)

BTU ANALYZER
Test time: mar .2021 18:11 calibration #:1
Test #:20 stream#:1 location no. UGDC FACTORY

	standatrd/dry analysis				saturated /wet analysis		
	MOLE%	BTU*	R.DEN.*	GPM**	MOLE%	BTU?*	R.DEN.*
METHANE	94.939	963.02	0.5264	0	93.373	944.28	0.5182
ETHANE	1.39	43.91	0.0251	0.6471	2.378	42.17	0.0247
PROPANE	0.889	15.83	0.0102	0.1839	0.656	16.53	0.01
I-BUTANE	0.19	4.21	0.0032	0.0523	0.157	5.12	0.0032
N-BUTANE	0.134	5.17	0.0027	0.0421	0.131	4.29	0.0026
I-PENTAN	0.059	2.03	0.0013	0.0185	0.05	1.99	0.0012
N-PENTA	0.029	0.93	0.0006	0.0084	0.023	0.91	0.0006
(C6+)	0.079	3.79	0.0025	0.0339	0.077	3.92	0.0015
MISTURE	0	0	0	0	1.74	0.88	0.0108
NITROGE	0.399	0	0.0036	0	0.365	0	0.0025
(CO2)	1.9	0	0.0163	0	1.051	0	0.016
TOTAL	100.008	1038.89	0.5919	0.9862	100.001	1020.09	0.5913

UNCORRECTED FOR COMPRESSIBILTY AT 60 60ºF & 14.73PSIA
** LIQUID VOLUME REPORTED AT 60ºF

		STANDARD /DRY ANALYSIS		SATURATED /WET ANALYSIS	
MOLAR MASS	=	17.138		17.153	
RELATIVE DENISTY	=	0.5928		0.5934	
COMPRESSIBILITY FACTOR	=	0.9978		0.9977	
HEATING VALUE	=	22938	Btu\lb	22538	Btu\lb
HEATING VALUE	=	1040.6	Btu\CF	1023.5	Btu\CF
ABSOLUTE GAS DENSITY	=	45.3666	Btu\1000CF	45.4117	Btu\1000CF
UNNORMALIZED TOTAL	=	100.038			

LAST CALIBRATED WITH CAGAS OF 1050.3 BTU/CF JAN 10.99 16:31
C6+ LAST UPDATE: MAR.02 9814:11
C6+ BTU/CF 5065.8,C6+ MOL.WT.92.00

Figure 8 Gas Derivatives Company Gas Analysis By O.G.C

BTU ANALYZER
Test time: mar .2021 7:19 calibration #:11
Test #:165 stream#:1 location no.DAMIETTA P.S

	standatrd/dry analysis				saturated /wet analysis		
	MOLE%	BTU*	R.DEN.*	GPM**	MOLE%	BTU?*	R.DEN.*
METHANE	90.1	711.02	0.4264	0	89.463	643.3	0.5175
ETHANE	5.32	33.62	0.0211	0.4471	2.5	31.17	0.0248
PROPANE	0.958	10.63	0.0202	0.172	0.956	15.53	0.01
I-BUTANE	0.88	5.21	0.0032	0.0311	0.657	4.18	0.0032
N-BUTAN	0.234	2.16	0.0027	0.0421	0.141	5.29	0.0026
I-PENTAN	0.021	1.1	0.0018	0.0184	0.159	3.99	0.0015
N-PENTA	0.053	0.93	0.0006	0.0064	0.023	1.91	0.0006
(C6+)	0.053	2.1	0.0025	0.031	0.077	2.92	0.0025
MISTURE	0	0	0	0	2.99	2.88	0.0109
NITROGE	0.371	0	0.0016	0	0.9695	0	0.0035
(CO2)	2.01	0	0.0133	0	2.078	0	0.016
TOTAL	100	766.77	0.4934	0.7481	100.014	711.17	0.5931

UNCORRECTED FOR COMPRESSIBILTY AT 60 60ºF & 14.73PSIA
** LIQUID VOLUME REPORTED AT 60ºF

		STANDARD /DRY ANALYSIS		SATURATED /WET ANALYSIS	
MOLAR MASS	=	17.138		17.153	
RELATIVE DENISTY	=	0.5928		0.5934	
COMPRESSIBILITY FACTOR	=	0.9978		0.9977	
HEATING VALUE	=	22938	Btu\lb	22538	Btu\lb
HEATING VALUE	=	1040.6	Btu\CF	1023.5	Btu\CF
ABSOLUTE GAS DENSITY	=	45.3666	Btu\1000CF	45.4117	Btu\1000CF
UNNORMALIZED TOTAL	=	100.038			

LAST CALIBRATED WITH CAGAS OF 1050.3 BTU/CF JAN 10.99 16:31
C6+ LAST UPDATE: MAR.02 9814:11
C6+ BTU/CF 5065.8,C6+ MOL.WT.92.00

Figure 9 Gas power station Analysis By O.G.C

3.2 The Results of Implantation a Maneuver Scenario Route

- The Rich Gas Produced from el wastany Production Plant supply Gas Derivatives Company which is very efficient compostion for propane and LPG production.

- In another situation the laen natural gas produced from EDCO supply electric power station with low efficient BTU value .

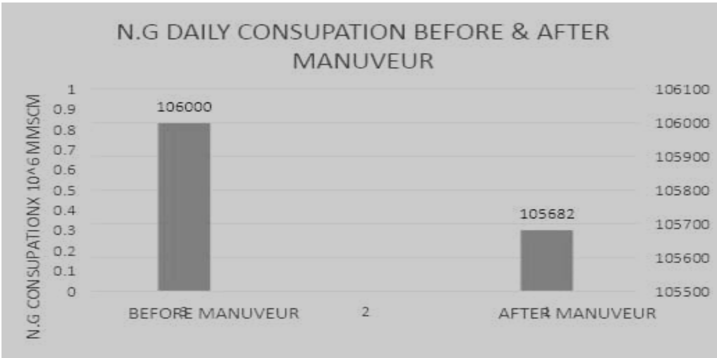

Figure 10 The Daily N.G Consumption Before & After Maneuver

Before using an online gas chromatograph & without maneuver scenario route with a daily gas consumpation = 106000x10^3 m3\day

While with the using the online of online gas chromatograph and with the maneuver scenario route=105682 x10^3 m3\day, therefore the efficiency increased by = 0.3% daily as shown fig 10

3.3 Feasibility Study for Using Online Gas Chromatograph with machine learning software on the networkgrid

TABLE 1

O.G.C TOTAL PRICE

	Activity	*Item price\ €*
1	*Unit price for Online Gas Chromatograph*	*25000*
2	*Accessories and installation materials and spare parts*	*5000*
3	*Machine learning software / Engineering Activits*	*1000*
4	*Civil works activates*	*3000*
5	*Commissioning & start-up works*	*2000*
6	*Fiber optics wires*	*3500*
7	*Transportation*	*500*
8	*Operation and observation & maintenance*	*1000*
9	*Fees*	*2500*
	Total price	*40000 €*

- 320 Gas terminal point x 40000 $ unit price O.G.C = 12800000 $
- Natural gas price = 0.1 m3/ $
- Consumption Reducation by (-0.03%) daily = 480 x 10^3 m3\day
- Cost for purchasing O.G.C / daily consupation reduction = 20,223,000 $ \48,000 $ m³\ days = 421 day
- 14 months the fesiable breakdown cost of using O.G.C for natural gas network grid

4 MACHINE LEARNING PROGRAM TO ADAPT A PROPOSED NATURAL GAS FRAMEWORK GRID BY USING ONLINE GAS CHROMATOGRAPH .

Gas Chromatography have to be install on gas Measurement metering Stations at Entry and Exit terminal Points, Entry Points connected to foreign importation pipelines , LNG regasification terminals, Entry points from national production fieldsand Points of interconnection with local distribution networks , Points of conjunction with the premises of Final Consumers directly connected to the Gas Transmission Networkis a commonly used analytic technique research identification and quantitation of compounds also a frequently used technique designed, manufactured, tested, installed and commissioned as per applicable international codes and standards, following the regulations, requirements and operation as well, maintenance and managing procedures. [26][22], [23], [23]

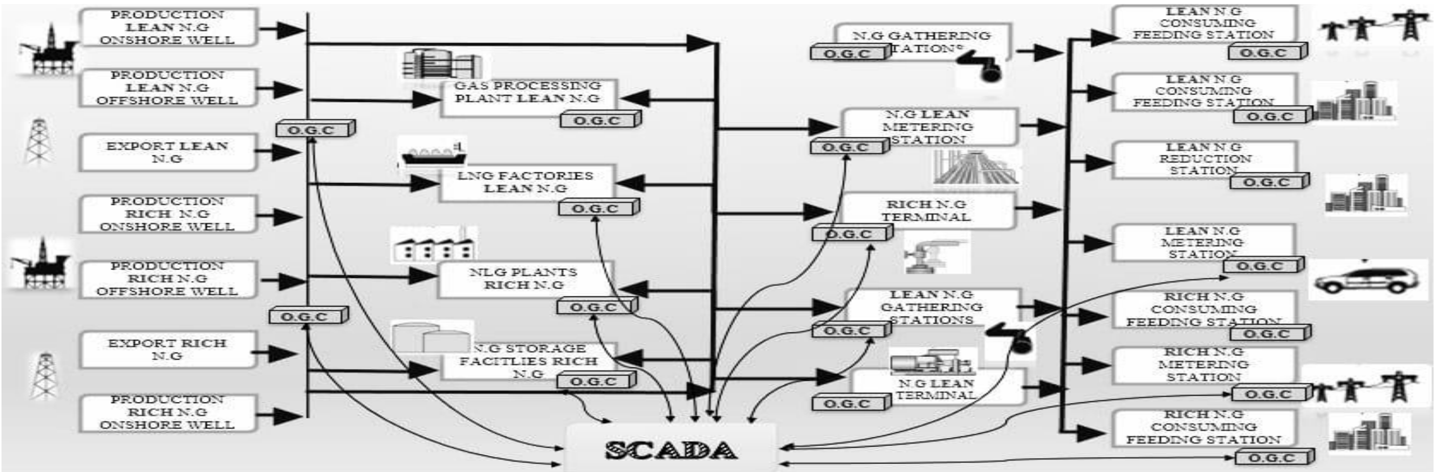

Figure 5 Smart Framework with ML SOFTWARE

Machine learning (ML) is used to teach machines how to handle the data more efficiently. Sometimes after viewing the data, we cannot interpret the extract information from the data mathematicians and programmers apply several approaches to find the solution of this problem which are having huge data sets. Machine Learning relies on different algorithms to solve data problems automatically.
All algorithms learn some kind of patterns from the training dataset and apply them to the test data set for prediction or classification. The workflow of supervised machine learning algorithms. [12] The petroleum industry heavily relies on sensors that are installed to collect various types of data. This massive amount of structured and unstructured data collected from those sensors usually require human analysis and intervention. Evidently, models attempt to come up with relationships between inputs and output state variables without any regard for the physical behavior of the system.
To transform the dataset into purposeful and logical information, data mining approaches assimilate visualization and statistical techniques and trend recognition patterns. Pattern identification and general data description is achieved via descriptive mining. While, predictive modelling depends on existing variable interpretation for future variable prediction. The algorithms utilize past and current information in the dataset to determine hidden trends for hypothesizing descriptive and predictive models with a decent capability for generalization Instead of shared database from gas chromatograph indices by serving the data acquisition (SCADA) observation. A machine learning approach is introduced to enhance the model by predicting the suitable route consuming flow for natural gas in the grid. Several types of machine learning models are built and tested on our data set and the result shows network gives the best prediction.
A more general approach building a database machine software of natural gas specifications using relationships, natural gas compound's compositions programmed can be analyze include input data
With the ability to process an image or recognizing patterns is suitable to be converted to solve and accelerate chemistry problems that involve chemical structures of natural gas.
Computing methods of chemistry system require remarkable resource and a relatively long time. Machine learning methods then provide alternative methods to estimate chemical properties.
The input of the model is the molecular structure and then the output is the parameter to estimate chromatographic retention time. The machine learning model can simply the simulation of chromatography behavior. [17], [18], [19] .
The Natural Gas samples Produced to determine the chemical properties and specifications at Gas Entry points processing and LPG factories Exit Points of processing factories and LPG factories and gathering terminal points and customer feeding stations. The gas chromatographs utilized to separate and measure and analysis natural gas samples.
We show our results in building machine learning models for chromatography that is essential for chemistry separation.

5 CONCLUSION

The fully controlling and supervision of an online gas chromtograph on the natural gas network grid with machine learning software to find solutions with huge data sets based on energy not volume an analysis of results are stored internally and communicate with SCADA systems relies solutions senrois Comply the contract with the client with more efficiency Reducing maintenance and Maintain the mechanical and instrumentation devices increase the accuracy on the metering devices which increase the customer satisfaction demand of gas which will be the most suitable and efficient BTU value , Dramatically Controlling the waste and unaccounted for natural gas increasing the national income cost.

ACKNOWLEDGMENT

This thesis would not have been possible without the guidance and the help of Dr Ahmed Bahgat Elsedawy, who is in one way or another contributed and extended his valuable assistance in the preprartion and completion of this study, it's a pleasure to thank him for this.

References

[1] https://defence-point.com/2019/12/31/egypt-awards-oil-and-gas-exploration-concessions-to-chevron-shell-and-mubadala/

[2] Natural Gas Engineering Handbook" by Boyan Guo and Ali Ghalambor

[3] Ikoku, C. U. (1984). Natural gas production engineering (pp. 516-pp). Wiley.

[4] M. Mohitpour, H. Golshan, A. Murray, Pipeline Design & Construction-A Practical Approach, 3th. Edition, 2007.

[5] https://unece.org/fileadmin/DAM/energy/se/pp/geg/geg6_March.2019/Item_5_Pakinam_Kafafi_Egypt.pdf.

[6] Natural Gas, 4th. Edition 2014. Oxford.

[7] Katz, Donald La Verne, ed. Handbook of natural gas engineering. McGraw-Hill, 1959.

[8] Arnold, K. (1996). Standard Handbook of Petroleum

[9] Donald L. Katz, Handbook of Natural Gas Engineering, New York, USA: McGraw-Hill, 1959

[10] https://www.researchgate.net/figure/Electricity-consumption-in-Egypt-Ministry-of-Energy-and-Electricity-2010_fig1_332061223.

[11] Handbook of Liquefied Natural Gas By Saeid Mokhatab, John Mak, Jaleel Valappil, David A. Wood

[12] Egyptian gas transmission network code (gas regulation)

[13] Arnold, K. (1996). Standard Handbook of Petroleum

[14] https://www.sciencedirect.com/topics/engineering/remote-terminal-unit

[15] https://www.gasreg.org.eg/wp-content/uploads/Final-Approved-TNC-April-2020.pdf

[16] A. Berthod, On the use of the Knox equation. II. The efficiency measurement problem, Journal of Liquid Chromatography. 12 (1989) 1187–1201

[17] https://www.researchgate.net/publication/339952951_An_Overview_on_Applications_of_Machine_learning_in_petroleum_Engineering

[18] Saied Mokhatab, John Y. Mak, Jaleel V. Valappil & David A. Wood. Handbook of Liquefied

[19] BTU analyzer operations manual. May 1993 / revised 12/93 A2

[20] Blumberg LM. Method translation in gas chromatography. 6,634,211. US Patent. 2003

[21] Vezzani S, Moretti P, Castello G. Automatic prediction of retention times in multi-linear programmed temperature analyses. J Chromatogr A. 1997;767:115–125

[22] L.R. Snyder, J.J. Kirkland, J.W. Dolan, Introduction to modern liquid chromatography, John Wiley & Sons, 2011

[23] I. Smith, Chromatography, Elsevier, 2013.

[24] S.A. Wise, L.C. Sander, W.E. May, Determination of polycyclic aromatic hydrocarbons by liquid chromatography, Journal of Chromatography A. 642 (1993) 329–349

[25] L.R. Snyder, J.J. Kirkland, J.W. Dolan, Introduction to modern liquid chromatography, John Wiley & Sons, 2011