ISSN 2286-4822
www.euacademic.org

EUROPEAN ACADEMIC RESEARCH
Vol. IX, Issue 12/ March 2022

Impact Factor: 3.4546 (UIF)
DRJI Value: 5.9 (B+)

Biofuel Production and Control

ISRA ALI BABUKIR ALHAG
College of Graduate Studies and Scientific Research
Karary University, Khartoum, Sudan
G. A. GASMELSEED
Associate Professor
University of Science and Technology, Khartoum, Sudan
AHMED AZAIN
Associate Professor
Khartoum University

Abstract

Climate change is the significant challenge in the world; it is an environmental issue and causes a serious sustainable development problem that affects social and economic sectors. The increased transportation and industrial activities are effect of air quality or pollution and causes global warming, acid rain, and ozone depletion.

Unsustainable energy or fossil fuel is major sources of air pollutions with increasing greenhouse gas (GHG) emission. To avoid this problem, renewable energy that produced through biological processes must be used. Ethanol is that made by fermentation, It is produced from sugarcane or other crops. Ethanol is a renewable energy, and cleaner alternative to fossil fuels. Production and demand of ethanol is growing day by day. The objective of this study is to enhance the production of ethanol to obtain high purity, there of using isotropic distillation.

A control strategy was developed, the transfer functions were identified and the system is investigated for tuning and stability .The results help in construction of suitable controllers for each loop.

Keywords: biofuel, ethanol, isotropic, distillation, design, control systems

1. INTRODUCTION:

The increasing problem of gases emissions needs alternative sources of energy. Ethanol is the suitable renewable energy resource can provide alternative sustainability Biofuel **[1]**. The most important factors which reduce ethanol production cost and economic are: an efficient of the raw material, high productivity, and high ethanol concentration in the distillation feed, **[1]**. Biofuel purposes products for either transport or heating, first: Bioethanol is produced from agricultural products including starchy and cereal crops such as sugarcane, corn, beets, wheat, and sorghum . Second**:** Biodiesel is made from oil- or tree-seeds such as rapeseed, sunflower, soya, palm, coconut or Jatropha **[2].**

Bioethanol the (Ethanol) is an alcohol made by fermentation it produced in sugar or other crops **[3] ,** also called ethyl alcohol, is a chemical compound with chemical formula (C_2H_5OH or CH_3-CH_2-OH) Ethanol is used as a fuel and others usage **[4] .**

Ethanol had been known as a fuel in Sudan, and the product was named Nile Ultra E-10, Sudan had started using 10% ethanol mixed into petrol. Kenana is a pioneer in the production of ethanol on a commercial scale in Sudan and has plans to expand its production. The company plans to increase the production from 65 million liters to 200 million liters per year (Kenana Company).

The good impact of biofuel in the sustainable development is: biofuel improved energy security, economic benefit, rural development, greater energy efficiency, and mitigation or reduce (GHG) emissions. But it had bad impact of the agricultural, water pollution, food security problems **[2].**

2. PROBLEM STATEMENT:

Distillation is one of the important tools that chemists and chemical engineers use to separate mixtures into their constituents. Because distillation cannot separate the constituents of an isotropic, the separation of isotropic mixtures is a topic of considerable interest **[5]**. So this difficulty led some early investigators to believe that azeotropes were actually compounds of their constituents **[5].**

An azeotrope that can be economically separated using a pressure swing – By contrast the composition of the water to ethanol azeotrope discussed earlier is not affected enough by pressure to be easily separated using pressure swings, **[5].**

3. OBJECTIVES:

1. Distillation of ethanol production to high purity at different conditions above azeotropic point.
2. Obtaining high purity ethanol (99.99) to be used as biofuel.
3. Development of control strategy, Stability analysis and tuning.

4. METHODOLOGY:

It is contains information about methods and materials used in the dissertation such as: Process description in distillation columns**,** Basic distillation equipment (A vertical shell where the separation, Column internal such as trays, A re boiler, A condenser, A reflux drum), **[6].** Basic elements of control loop (The process (e.g. . distillation column), The measuring element (sensor), The controller, The regulating element (valve), The controlled, The manipulated variable , The disturbances, The load variable) . **[7].** type of control, and of introduction, or brief history about MATLAB software, also the methods to determine the Distillation ethanol and information the design. Also the methods for tuning controllers, stability test and determine the overall system response and control.

4.1 Process Description and Control:

Distillation is the separation methodology was done by using simple distillator at a temperature of azeotropic point occur at (89^{o} C), azeotropic system is (Ethanol – water), was using of 12% ethanol .This is carried out above the isotropic point to obtain70% of ethanol. After first distillation the distilled concentration by added pure ethanol , it was added to increase the concentration of ethanol to (94%) and then was it pass through a second distillator to obtain (98%) of ethanol ,and after that was used (Molecular Sieve) by used adsorption to determine the concentration of the ethanol to produce high purity ethanol about (99.99) by using Azeotropic distillation to be used as bio-fuel. Also was determining the control strategy of system, System Stability and Tuning, and overall system response. By using the MATLAB software, solving of technical computing problems is faster than with traditional programming languages.

4.2 System Stability and Tuning Identification:

System Identification methods may be used to build mathematical models of dynamic systems based on observed and measured input and output data from the system. System Identification is defined as: Identification is the determination, on the basis of input and output, of a system within a specified class of systems, to which the system under test is equivalent.

A dynamical mathematical model in this context is a mathematical description of the dynamic behavior of a system or process in either the time or frequency domain. Mathematical models of a system have been obtained in transfer function form, and then these models can be analyzed to predict how the systems respond in both the time and frequency domains. Stability in mathematics is a state of systems or, in other words, a mathematical characteristic that is usually mentioned in conjunction with the solution of a differential equation where the solution of the differential equation is said to be stable or unstable The stability of the system are also determined by Routh criterion which has special technique to show if the system is critical stable, stable or unstable **[8].**

MATLAB is the graphics system. It includes high - level commands for two – dimensional and three - dimensional data visualization, image processing, animation, and presentation graphics. It also includes low-level commands that allow you to fully customize the appearance of graphics as well as to build complete Graphical User Interfaces on your MATLAB applications, **[9].**

5. RESULTS AND DISCUSSIONS:

5.1 RESULTS

5.1.1 Compositions of Ethanol

Table 1. Compositions of Ethanol.

feed $x_{f\ etho}$	0.18
distilled $x_{D\ ethoh}$	0.7
waste $x_{W\ etho}$	0.01

5.1.2 Number of stages and minimum reflux ratio According to McCabe - Thiele method:

Equilibrium data:

$$\mathbf{y = \alpha_1 * x/(1 + (\alpha_1 - 1) * x)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \mathbf{(1)[6]}$$

Where:

$\alpha_1 =$ is the relative volatility, obtained from the equilibrium data.

$\alpha_1 = 2.62$

Table .2. Values of The equilibrium data

x	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
y	0.22	0.39	0.52	0.63	0.72	0.79	0.85	0.91	0.95	1

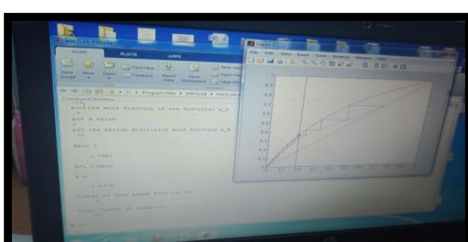


Fig .1. Number of stage by McCabe – Thiele method .

From the figure:

R_{min} = 1.7981

R = (1.3 time R_{min})

Feed location stage number 4 (as from top)

Total number of stage 14

Table 3. Summary of the design of sieve tray distillation column

N_m	7.04 = 7.00 stage
N_{actual}	13.55 = 14.00 stage
R_m	2.88
R	3.75
Feed location	After 6.9 stages from top
F_{LV}	0.7o1
Column diameter	2.77
K1 (constant)	0.07
Plate spacing	0.48m
Volumetric flowrate	0.147m³/s
Mass flowrate	5.377 kg/s
Molar flowrate	116.9 kmole/s
A_c	6.0300m2
A_{dc}	0.9045m2
A_n	5.125m2
h_w	75mm
Number of holes	24492 holes
Plate pressure drop	112.63mm
Column height	25.58m

5.1.3 The following is the Control strategy

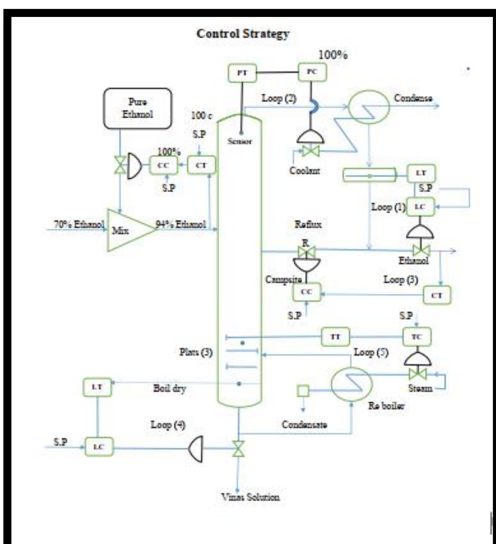
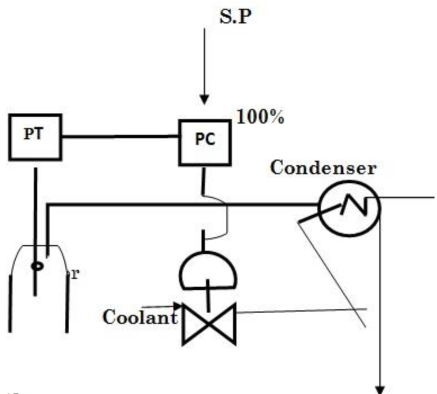


Fig. 2. Control strategy of the distillation column

5.1.4 Tuning and Stability Analysis

Transfer Functions identification

- **Loop (2)**



1 – P – Action

$G_{(c)} = Kc$

$G_v = \frac{1}{(S+0.5)}$ (The Control valve)

$G_p = \frac{1}{(S+0.2)}$ (The Process)

$G_m = \frac{1}{8S}$ (The sensor and transmitter)

The following is the Block Diagram of loop (2)

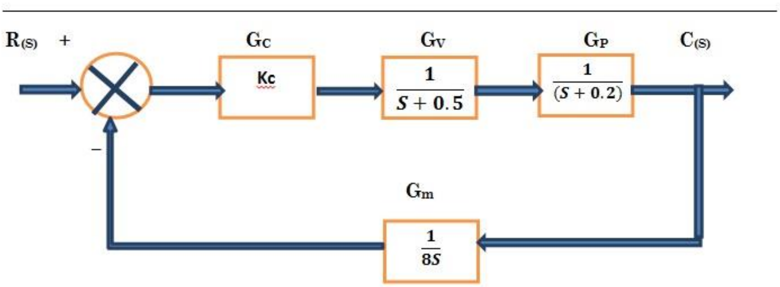


Fig.3. Block diagram of loop (2)

5.1.5 System Stability Routh-Hurwitz and Direct Substitution Method:

- **Application of Routh-Hurwitz Array:**

Determination of ultimate gain (Ku):

The characteristic equation:

$$8S^3 + 5.6S^2 + 0.8S + kc = 0 \qquad \text{.................................} \qquad (2)$$

- **Using Routh -Hurwitz Array Method :**

-Determination of ultimate gain (Ku) and ultimate Period (Pu) :

$K_c = 0.56$ $K_u = K_c = 0.56$

$$P_u = 2\pi/\omega c_0 \qquad \text{.................................} \qquad (3)$$

$P_u = 19.87$ sec

- **Using Direct substitution Method :**

$K_c = 0.5599$ $K_u = K_c = 0.5599$

$P_u = 19.86$ sec

5.1.6 Root-Locus and Bode Diagram:

Take the previous Open loop transfer function (OLTF), using MATLAB to plot Root-locus, Bode Plot and obtain the ultimate gain (k_u), and Ultimate period (P_u) :

- **Root – Locus :**

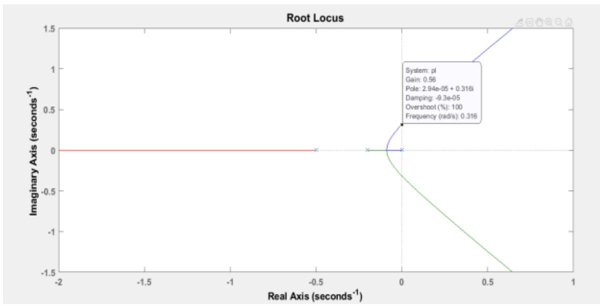


Fig .4. Root-locus diagram loop (2)

- **Bode Plot**:-

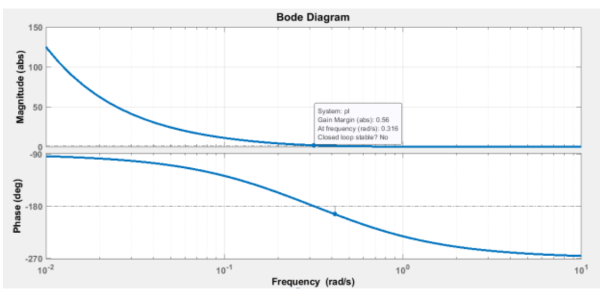


Fig .5. Bode diagram loop(2)

Table .4. Average values of ultimate gain (Ku) and ultimate Period (Pu)

Method	ultimate gain Ku	ultimate period Pu(sec)
Routh-Hurwitz	0.56	19.8709
Direct substitution	0.5599	19.8609
Root-locus	0.56	19.88
Bode	0.56	19.88
Average	0.56	19.875

5.1.6 Determination of Adjustable Parameters:-

- Using Ziegler-Nichols **(Z - N)** tuning controller, the adjustable parameter for.
- Proportional controller (kc), Integral controller (τ_i), derivative controller (τ_d):

Table (5): Ziegler-Nichols Stability and Tuning System of Average Loop:

Type of controller	Gain Kc	Integration time(τ_i),	Derivation time(τ_d):
P	0.28	-	-
PI	0.252	16.56	-
PID	0.336	9.94	2.484

5.1.7 Response of the System:

1. System response for P-Controller:

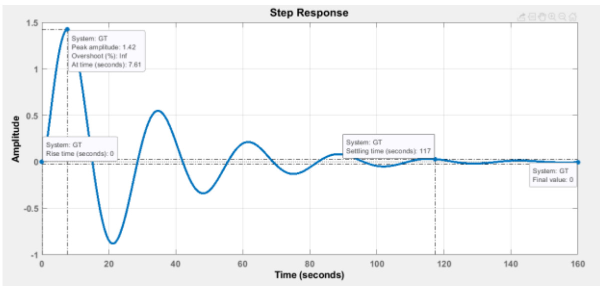


Fig .6. System response using P-controller

Table .6. Characteristics of closed loop response with P-controller

Characteristic	**Value**
over shoot	0.62
Rise time (sec)	0
Response time (sec)	117
Decay ratio	0.387
Beak time (sec)	7.61
Dampness coefficient(ξ)	0.15
Offset	-1

It follows that the system is under damped, zeta (ξ) < 1 . 0

2. System response for Pl-Controller:

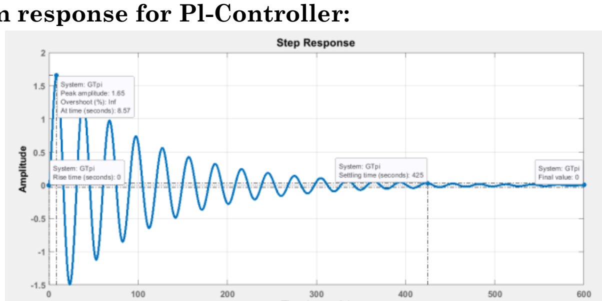


Fig .7. System response using Pl- Controller

Table 7. Characteristics of closed loop response with Pl-controller

Characteristic	**Value**
over shoot	0.88
Rise time (sec)	0
Response time (sec)	425
Decay ratio	0.77
Beak time (sec)	8.57
Dampness coefficient(ξ)	0.041
Offset	-1

It follows that the system is under damped, zeta (ξ) < 1 . 0

3. System response for PlD-Controller:

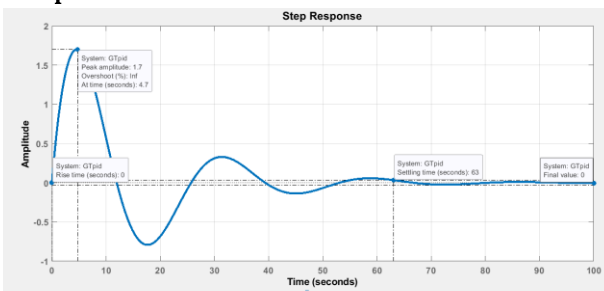


Fig (8) : System response using PlD - Controller

Table 8. Characteristics of closed loop response with PlD-controller

Characteristic	Value
over shoot	0.44
Rise time (sec)	0
Response time (sec)	63
Decay ratio	0.19
Beak time (sec)	4.7
Dampness coefficient(ξ)	0.25
Offset	-1

It follows that the system is under damped, zeta (ξ) < 1 . 0

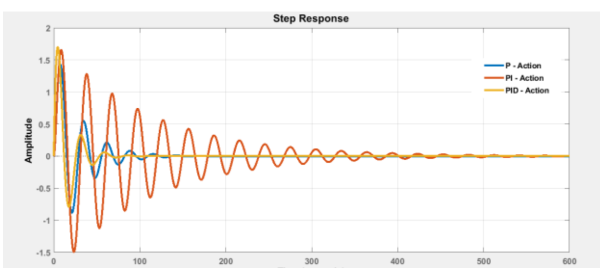


Fig. 9. Comparison between different types of controllers

Other Loops , loop(1), loop(3) ,loop(4) , loop (5) are treated similarly for P ,PI , PID.

5.2 Discussion of the results:

It is importance that about awareness of ethanol production advance technological have been made in a few year ago which can lead to increase efficiency in ethanol production, one significant of these is (azeotropes distillation) to production high purity ethanol. Industrial alcohol from distillation of fermentation material such as molasses, the underlying economic problem of this industrial is the cost of raw material this led the producer of industrial alcohol to be always in search of cheaper, useable raw materials.

From the design, equations and by using constant and data component are ethanol and water , rate of feed (F), rate of distilled (D), rate of waste (w) at temperature of (40^o C) and 70% of ethanol concentration. Many design requirements calculated the most important were:

Reflex ration (minimum – actual) (R_m – R)

Number of plates (minimum – actual) (N_m – N)

Feed plate location, height (H) and diameter of the tower (D), area of the tower (total area a^2 , active area (h_n m^2). Net area (A_n m^2).

A result showed that (70% v/v) ethanol could be obtained from fermentation, the fermented liquid was filtered and introduce to simple distillation device to obtain ethanol. Design of distillation column was done and minimum number of stage was (7.04), and actual number of stage was (13.55) ,with reflux ratio (3.75), with column diameter (0.701 m), and height (25.58 m) in sieve tray column.

The control system was developed, analyzed for stability and tuning .The controller that gave her performance was selected and recommends to be installed.

A control strategy was developed and the transfer functions were identified. The characteristics equation, the open loop transfer function (OLTF), and over all transfer function were obtained for stability analysis and tuning.

The methods used for tuning and stability analysis were, Routh – Hurwitz, direct substitution, Root- Locus and Bode plot to determine the ultimate gains (Ku) and the ultimate periods (Pu).

The response of the system was plotted by inserting the adjustable obtained parameter (K_u, τ_i ,τ_d) Matlab software was used to determine the system stability analysis and tuning. The results of this study were for five loops, the average ultimate gain Ku was (40.6398) loop1, (0.56) loop2, (2.3452) loop3, (5.25) loop4, (0.8798) loop5, and the average ultimate period was Pu (0.4278 sec) loop1 , (0. 19.875 sec) loop2 , (0.05099 sec) loop3, (168.5228 sec) loop4, (5.3207 sec) loop5, and introduce into the Ziegler Nichols table to calculate the optimum parameter for (P,P1,PID) to the five loops then the minimum over shoot was taken to select the controller that gives the best performance for each loop and it was (P) for loop1 (0.659) , and (PID) for loop2 (0.44) , loop3 (0.428) , loop4 (0.429) , loop5 (0.75) . Finally the stability of the system was checked by using Routh array analysis and the system was found to be stable.

6. CONCLUSIONS AND RECOMMENDATIONS:

6.1 Conclusions:

Biofuel is the important opportunities and challenges for sustainable development, and it is also can help to reduce climate change problems. There is therefore to, develop the biofuel industry. So that emerged the idea of the aim of this study, is to produce or obtaining high purity ethanol (99.99) to be used as bio-fuel by using Azeotropic distillation and control strategy, Stability, analysis and tuning. The benefits and costs of biofuel vary, according to: the type and geographical area of the feedstock, energy efficiency, impacts of the product on Green house gases (GHG) emissions, and other environmental effects, considerable biofuel efficient producing and competitiveness. The gases emissions, causes significant threat, and negative environmental social economic impacts, so sustainable development in Sudan and the world. In order to avoid the bad environmental impact of emission it must reduce, minimizing the use of fossil fuel by using alternative renewable green energy , To dealing with the climate change problem via adaptation or mitegation the global worming phenomena that is to prevent, minimize the formation of emission at the source itself. This can be by use fuel full clean combustion in the transportation sector. Ethanol from fermentation is renewable resource suitable for use as feed stack for production of high purity of biofuel. The majorty of the study has focus on fuel ethanol. According to the results of this study it is possible to produce high purity ethanol by azeotropic distillation, the cost of production is research can able and it can make good economy returns to producers. It is actually a good biofuel option beside or alternative for gasoline or fossil fuel. There is some problem related to bioethanol production such as: The availability of raw materials for production which affects the availability of feed stock of bio-ethanol can vary considerably from season to season and depend on geographic location and amount of rain precipitation also the price of the row material is volatile and unstable which it can affects the cost of the bioethanol .The design for of distillation column was done and all consideration were calculated . Tight digital control system has to introduced, the system was analyzed tuned, type of the controller with the best performance and minimum overshoot was selected.

6.2 Recommendations:

It is recommended for further studies on:

- Ethanol production by a zeotropic distillation to high purity is less cost and easy to occur.
- According to increasing in demand of biofuel this will result fuel problem because the available of molass related a time that crops planted (sugar cane or other crop) will not be enough, so it is better to find another feedstock source for biofuel production and more sugar bearing plants such as corn , sugar beet, … etc.
- Development and expand kenana biofuel plant and increase it's capacities.
- Benefit from another countries experiences that applied blending system of biofuel and gasoline
- It is better to find an alternative source for biofuel production except the (molass) although molass is good but it is not available all of the year.
- It is recommended that to make more research and study for biofuel in order to use as the jet fuel
- It is recommended that the Conventional Control system must be changed to the digital control systems, because of its more sensitivity.
- The control system purposed in this study has to be interface into discrete and system in the distillation column.

REFERENCES

(1) P. ALVIRA, E. T.-P., M. BALLESTEROS, M.J. NEGRO 2010. <Pretreatment technologies for an efficient bioethanol production process based on enzymatic hydrolysis. pdf>. Bioresource Technology, 101.

(2) Annie Dufey. September 2006 . **Biofuels production, trade and sustainable development: emerging issues,**Environmental Economics Programme/Sustainable Markets Group

(3) HTTP://EN.M.WIKIPEDIA.ORG/WIKL/BIOFUEL02072018101540.

(4) HTTP://EN.M.WIKIPEDIA.ORG/WIKL/ETHANOL020720181015840.

(5) Jump up to: a b c d e f g h i j Hilmen , Eva- Katrine (Novembe2000). "Separation of Azeotropic Mixtures: Tools for Analysis and Studies on Batch Distillation Operation" (PDF) Norwegian University of Science and Technology, Dept. of Chemical Engineering . Archived from theboriginal (PDF)on15 June2007 . Retrieved 24 March 2007 .

(6) Seader, J. D., and Henry, Z., Distillation Design, Mc Grow Hills, New York, (1992).

(7) Gurashi . A. Gasmelseed .2016. ATEXT BOOK OF CHEMICAL ENGINEERING PROCESS CONTROL, G. TOWN. Third Edition.

(8) Rouche.N.1977,et al,: stability Theory by Liapunov's Direct Method .Springer, New York, ISBN 0-387-90258-9.

(9) Xue, D. 2007. Linear feedback control: analysis and design with MATLAB . Philadelphia: Society for Industrial and Applied Mathematics.