Renewal Energy from Cotton Stalk for Generation of Electricity in Gezira State

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Abstract: *The Sudan is endowed with cotton in very huge areas. Cotton stalk creates a continuous transfer of plant diseaseand needs to be deeply derooted and burnt out, producing carbon dioxide emission and affect the environment.Solution methods were undertaken taking into consideration the control of gas emissions and environmental protective. One of these methods is to collect the cotton stalk, put them in compressed bundles ready for burning and production of super-heated steam for electricity generation. The emitted gases including carbon dioxide have to passthrough an absorption column to remove the Co_2 with the absorbent, the absorbate may be sodium by carbonate which can be recovered and reused. A control strategy has to be developed and the transfer functions of controlling loops have to be identified. The loops were subjected tostability analysis and tuning. The loops with minimum interaction have to be selected and installed into the system. Acomparison between continuous and digital tuning was compared and presented. Thecontinuous method is easy to apply and clear.*

Keywords: cotton stalk, super-heated steam, electricity generation, environmental protection

1. Introduction

Sudan has about 2,500,000 acres of land planted by cotton in Gezira, cotton fiber was collected, sorted, and fabricated. The stalks or stems of cotton plants were collected and burnt out as they incubate bacteria causing plant disease for the following seasons, they also emitted Co_2 all over the area and therefore contributed to global warming. The cotton stalk contains cellulose, hemicellulose, and lignin and can be used as feedstock for the production of bioethanol fuel, furfural, and cellulose acetate. Pretreatment with dilute acid at ambient temperature is processed for biomass processing. The process hydrolyzes the cellulose to be made into sugar. It has been tried to convert cellulose to cellulose acetate, where the hemicellulose sugar is separated for bioethanol production, it must be known that wood and cotton are the major recourse for cellulose products including papers, textiles, construction materials, and cupboards, it is estimated that 0.35 billion kilogram of cellulose acetate is produced internationally per year, (1). Cellulose acetate is used in textiles with low cost, hardness, and high transparency. Cellulose acetate fibers are designed to absorb toxic gases and particulates of smoke components. Cotton stalks or biomass can be collected, made into bundles, and burnt out to generate steam which is introduced into a turbine to generate electricity. Biomass can be heated up to 120^0C to produce hemicelluloses from which water is evaporated to produce furfural. Furfural is identified as one of the most significant value-added products, it is a typical product which could be obtained from hemicelluloses in raw biomass [1], and is also an important chemical produced in lignocelluloses that could further be transformed into fuels and useful chemicals, which are used in crude oil refining, plastic, Pharmaceutical, and agro-medical industries[2]. Different techniques for the production of hemicelluloses from raw biomass have been investigated [3-4]. In additional to the three main components in biomass, hemicellulose is a promising and effective resource to produce furfural with high yield and selectivity. Pretreatment methods are divided into three groups including, physical, chemical, and biological methods. [5-6] Physical methods use mechanical action or heat to open -up the fiber structure and reduce the particle size to a nano, on the other side biological methods, [7] use fungal enzymes for the digestion of stalk biomass. The chemical treatment used dilute acids or basis to dissolve the biomass and change its composition [8-9], and the method of biochemical, and thermochemical conversion were also investigated [10, 11]. Although the hydrolysis of biomass to separate hemicellulose as sugar, the sugar content is insignificant and cannot be fermented to feasible alcohol production. All these methods can be developed to give biofuels, but the cost is expected to be high and not feasible. Therefore, the incineration method can be feasible and can be applied. The environmental impact has to be solved through tight closer and automatic control. A tight control strategy was developed, the transfer functions were identified, the overall transfer functions were obtained, and the system analysis, stability, and tuning were obtained and addressed. In this type of control, proportional action was overlooked as a more effective and tight control is essential. The conventional control system was developed and made into digital or discrete control systems. The difference between analog and discrete or computer control was investigated and compared.

1.1 Objectives of the study

1) Investigation of cottonwood stalk as a renewable source of energy.
2) Protection of the environment from greenhouse gases produced upon burnt out of cotton stalk (CS).
3) Development of a control system in continuous and digital format to tightly control the incinerator from any leakages or emission of green gases to theatmosphere.

1.2 Control Strategy

A schematic diagram of the incinerator was developed as shown in fig (1).
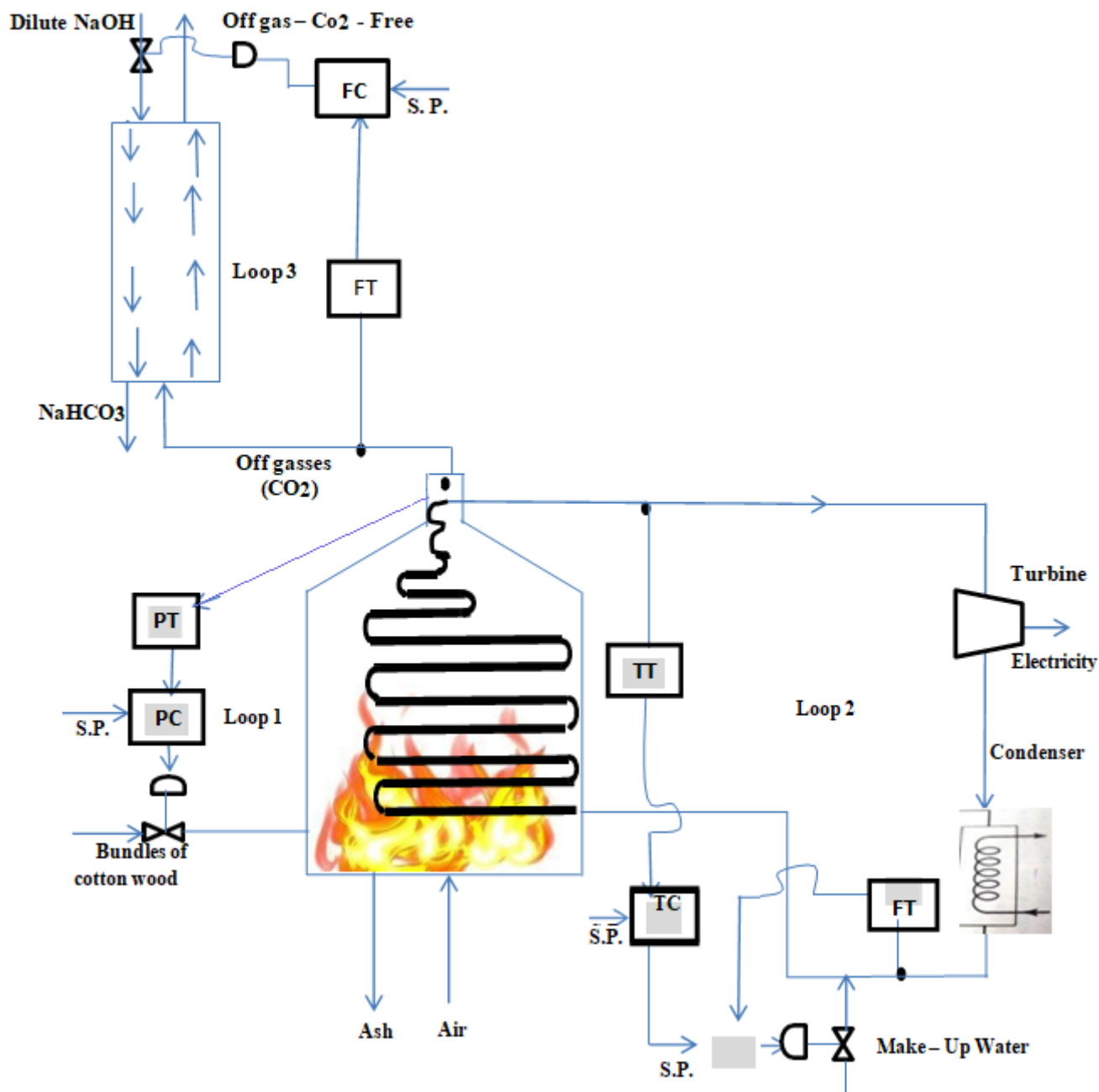

Figure 1: Control strategy for steam generation

Where:
Loop 1: CS bundles' feed manipulated by outlet exhaust pressure.
Loop 2: Control of make-up water flow cascaded with steam temp exit.
Loop 3: Control of carbon dioxide Co_2- absorbed manipulated by off-gasses flow

2. Methodology

The methods of treatment of cellulose biomass and separation of solids, hemicellulose, and lignin are dealt with elsewhere [12]. The incinerator is designed to accommodate the cotton wood bundles inside the boiler and produce steam which is super saturated and passed to the turbine for electricity generation, the remainder of the water vapor is condensed, recycled, and topped with the make-up fresh water. The process is continued with electricity made

available for areas in Gezira state, where they need electricity. The methodology of MATLAB for tuning and stability analysis was described elsewhere, (13). Z-N rules were applied to obtain the adjustable parameters for the loop. These adjustable parameters in the L- domain and their counterpart in the Z-domain we inserted into the open loop transfer functions to obtain the responses of the system.

Stability analysis:
The processes and analysis for the products obtained from biomass are expensive, difficult to design, and difficult to

control. In this study it was more useful to concentrate on tight and robust control of the incinerator, hence a control strategy was developed. The transfer functions were identified, stability and tuning analysis were calculated, the adjustable parameters were obtained from Z-N rules and inserted into MATLAB software and the system was simulated.

Calculations of stability and tuning parameters:
The following are the transfer functions for each element:
Taking a proportional controller

Transfer function identification (14)Loop1:
Gc1 = Kc1

$$G_{v(s)} = \frac{2}{1.5s+1}$$

$$Gp_1 \ (S) = \frac{0.8}{1.5s+1}$$

$$G_{m(s)} = \frac{1}{0.05s+1}$$

The block diagram:
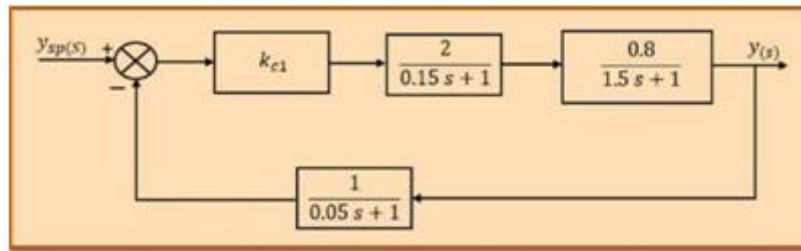
Figure 2: Block Diagram of Loop 1

The overall transfer function:

$$G_{(s)} = \frac{\pi}{1 \pm \pi l}$$

$$\pi f = K_{c1} \cdot \frac{2}{0.15s+1} \cdot \frac{0.8}{1.5s+1} = \frac{21.6 Kc1}{(0.15s+1)(1.5s+1)}$$

$$\pi L = K_{c1} \cdot \frac{1.6}{(0.15s+1)(1.5s+1)} \cdot \frac{1}{0.05s+1}$$

$$= \frac{1.6 Kc1}{(0.15s+1)(1.5s+1)(0.05s+1)}$$

The characteristic equation: $\pi L + 1 = 0$

$(0.15s + 1)(1.5s + 1)(0.05S + 1) + 1.16kc1 = 0$

$0.01125S^3 + 0.3075S^2 + 1.7S + 1 + 1.6kc1 = 0$

Using Routh-Hurwitz method:

Putting the characteristic equ. into Routh array:
$0.01125S^3 + 0.3075S^2 + 1.7S + 1 + 1.6kc; = 0$

Rows	Coefficients	
S³	0.1125	17
S²	3.075	10-16 kc1
S¹	16.63-0.59 kc1	0
S⁰	10-16 kc1	0

To get the ultimate gain, let:
16.63 / 0.59 = 28.2
∴ Ku= 28.2

Using direct substitution method:
• Set s = iw in the characteristic equation:
-0.1125iw3 ‹ - 3.075– 17 iw + 10 + 16kc1 = 0

Taking the real part:
-3.075 w²' + 10 + 16kc1 = 0

Taking the imaginary part:

$$-0.1125\ iw^3 + 17\ iw = 0$$

$$0.1125\ iw^2 = -17$$

$$W = \sqrt{\frac{17}{0.1125}} = 12.3 \text{ rad/sec}$$

Substitute the Value of cross over the frequency:

$$-3.075*(12.3)^2 + 10 + 16Kc1 = 0$$
$$\therefore Kc_u = 28.5$$

The ultimate period:

$$Pu = \frac{2\pi}{wco} = \frac{2\pi}{12.3} = 0.51 \text{sec}$$

Using Root–locus and MATLAB

Get the Open Loop Transfer Function:

$OLTF = 16Kc1 / (0.1125S^3 + 3.075S^2 + 17S + 10)$

MATLAB Format:
```
>> num= [16];
>> den = [ 0.1125 3.075 17 10];
>> rlocus (num,den)
```
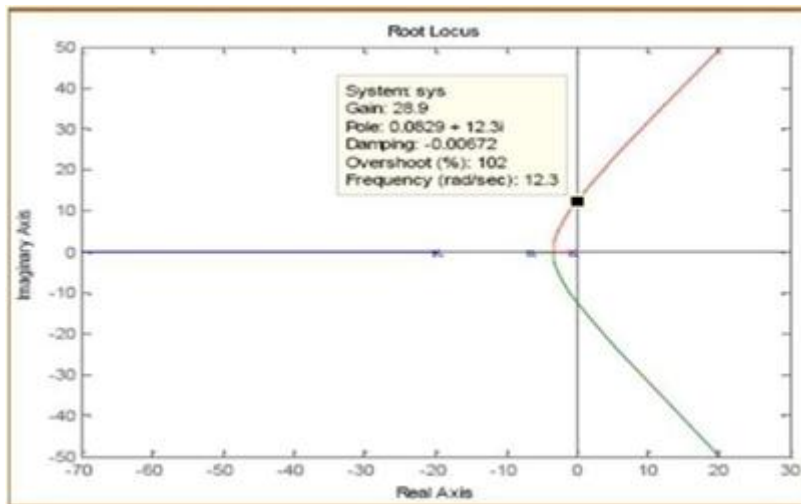
Figure 3: Root-locus Plot

From the figure:

$$K_u = 28.2$$

$$W_{co} = 12.3 \text{ rad/sec}$$

$$Pu = \frac{2\pi}{wco} = \frac{2\pi}{12.3} = 0.51 \text{sec}$$

Using Bode Plot and MATLAB:

$$OLTF = 16Kc1/(0.1125S^3 + 3.075S^2 + 17S + 10)$$

MATLAP format:
>> num = [16];
>> den = [0.1125 3.075 17 10];
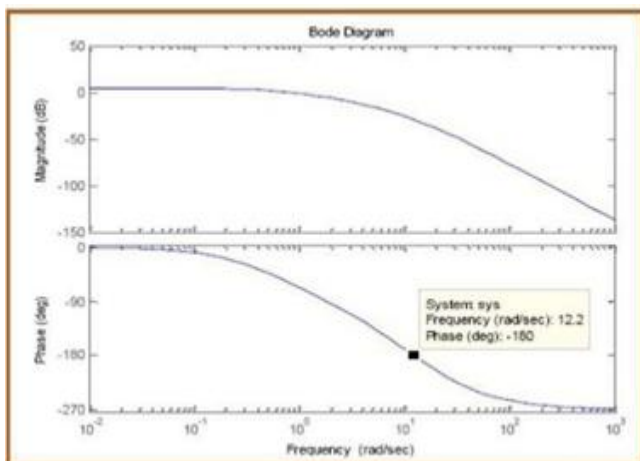>> bode (num , den)

Figure 4: Bode Plot in dB

From fig (4) at -180˚

$$W_{co} = 12.2 \text{ rad/sec}$$

$$Pu = \frac{2\pi}{wco} = \frac{2\pi}{12.3} = 0.515 \text{ sec}$$

To determine the Amplitude ratio value, AR should be converted from decibels (db) to absolute.

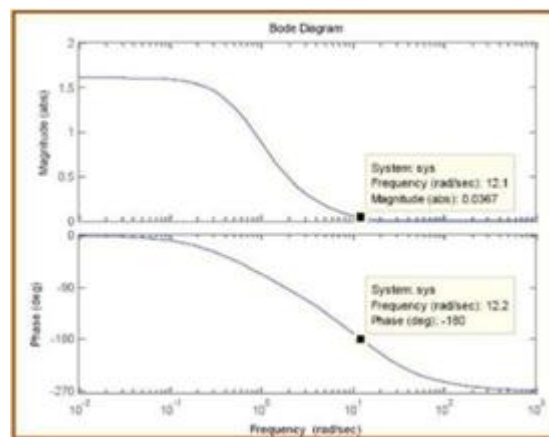This can be done using the following:

Using the formula: db = 20 log AR

Figure 5: Bode Plot in abs

From fig (5):

AR = 0.0367

$$K_u = \frac{1}{AR} = \frac{1}{0.0367} = 27.25$$

The following is Z-N tuning table:

Type of controller	K_c	I,S	D,S
P	0.5 K_u	-	-
PI	0.45 K_u	$\frac{Pu}{1.2}$	-
PID	0.6 K_u	$\frac{Pu}{2}$	$\frac{Pu}{8}$

$$Ku, Average = \frac{Ku1 + Ku2 + Ku3}{3} = \frac{28.5 + 27.25 + 28.9}{3} = 28.21$$

$$Pu, Average = \frac{Pu1 + Pu2 + Pu3}{3} = \frac{0.51 + 0.51 + 0.515}{3} = 0.511$$

The adjustable parameters are:
P-Controller:
Kc = 14.105

PI-Controller:

$$Kc = 12.69, t1 = \frac{Pu\ average}{1.2} = \frac{0.511}{1.2} = 0.426, s$$

PID-Controller:
KC = 16.92

$$\pi1 = \frac{Pu\ average}{2} = \frac{0.511}{2} = 0.256, s$$

$$\pi D = \frac{Pu\ average}{8} = \frac{0.511}{8} = 0.064, s$$

The response of the system after tuning:

For P-controller:

The closed-loop transfer function:

$$G\ (s) = \frac{1.6\ Kc1}{(0.15s + 1)(1.5s + 1)}$$

$$G\ (s) = \frac{1.6\ K}{1 + (0.5s + 1)(105s + 1)}$$

$$G\ (s) = \frac{1.6\ Kc2\ (0.05s + 1)}{0.01125s3 + 0.03075s2 + 17s + 1 + 1.6Kc2}$$

$Kc_1 = 14.105$

$$G\ (s) = \frac{1.6\ Kc1\ (0.05s + 1)}{0.01125s3 + 0.03075s2 + 17s + 1 + 1.6Kc2}$$

$$G\ (s) = \frac{1.128S + 1 + 22.57}{0.01125s3 + 0.03075s2 + 17s + 1 + 23.57}$$

MATLAB is used to plot the step response from the closed loop transfer function:

MATLAB format:
>> num=[1.128 22.57];
>> den=[0.01125 0.3075 1.7 23.57];
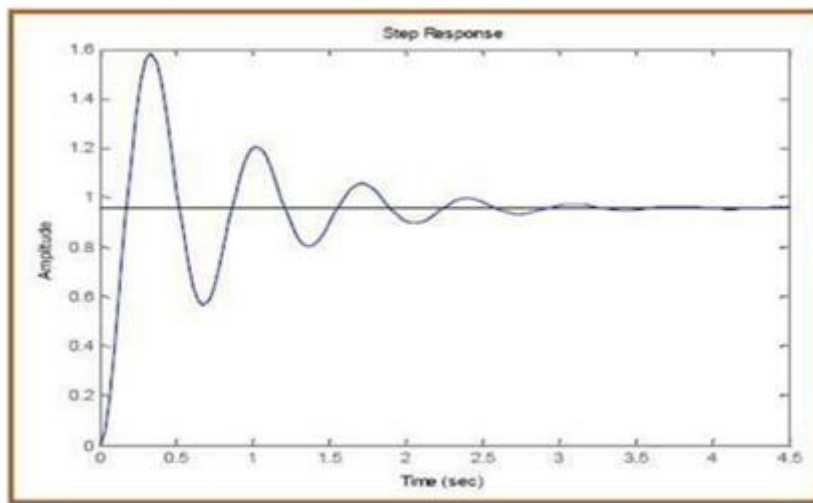
Figure 6: Response of the Continuous System

From fig 6:

Table 1: Design parameters

Parameter	Value
Peak amplitude or overshoot	243.3%
Rise time	0.25 sec
Decay ratio	0.411
Recovery time	3.5 sec

Conversion from Laplace transform to z – transform:

$$G\ (s) = \frac{1.128S + 1 + 22.57}{0.01125s3 + 0.03075s2 + 17s + 1 + 23.57}$$

MATLAB format:
>> s = tf ('s');
>> sys = (1.128*s+1+22.57) /

(0.01125*S^3+0.307s*s+23.57);
>> Ts = 1/100;
..>> sys_d= C2d) sys, Ts , ' Zoh')

The result appeared as follows:Transfer function:

$$= \frac{0.004907\ Z2 + 0.0008213\ z - 0.003897}{Z3 - 2.747Z2 - 0.7608}$$

Discrete Root Locus:
>> num Dz = [0.004907 0.0008213 - 0.003897];
>> den Dz = [1 – 2.74 2.509 -0.7608];
>> sys = tf (num Dz, den Dz, -1);
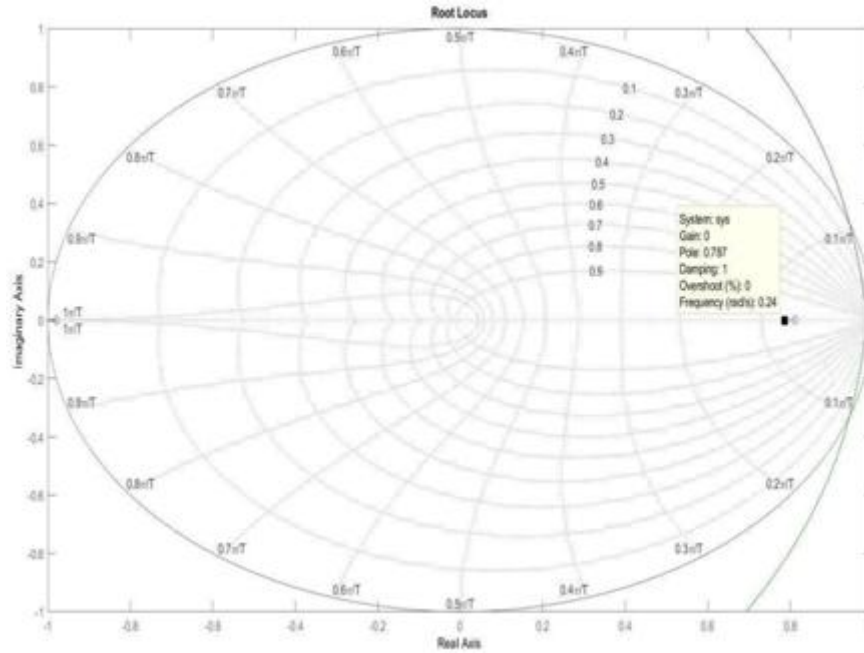>> locus (sys);
>> axis ([-1   1 -1 1])
>> Zgrid

Figure 7: r-locus in Digital format

Bode Plot:
>> numDz = [0.004907   0.0008213 - 0.003897];
>> denDz = [1 – 2.74 2.509 -0.7608];
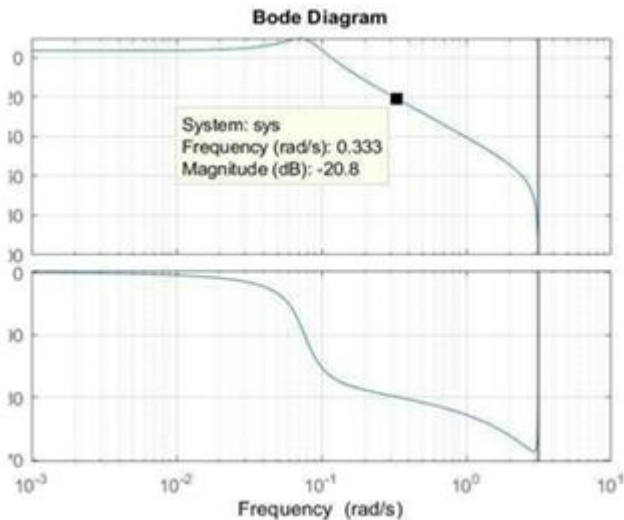>> sys = tf (numDz , denDz , -1);
>> bode (sys);
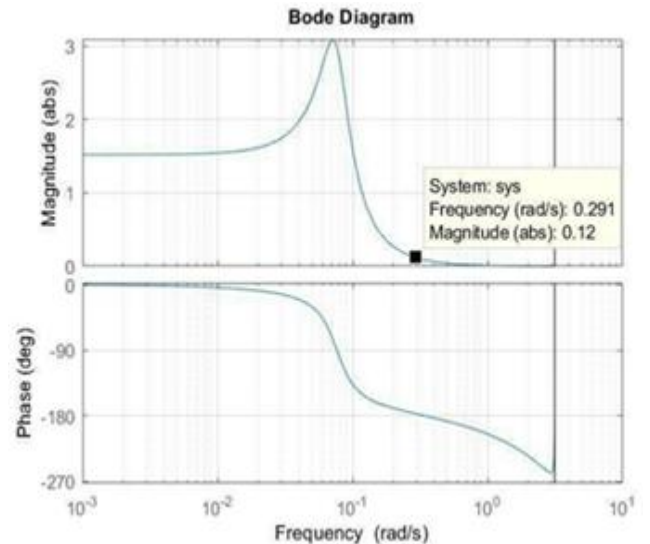>> grid

Figure 8: Bode in dB in digital format

Figure 9: Bode in abs in digital format

Step response in the digital control system:

>> numDz = [0.004907 0.0008213 - 0.003897];
>> denDz = [1 – 2.74 2.509 -0.7608];
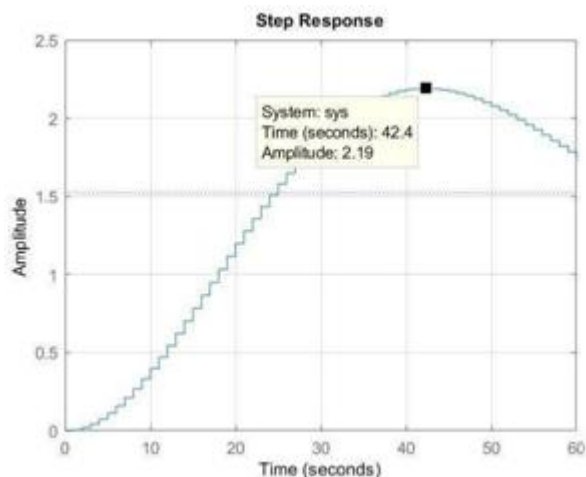>> sys = tf (numDz, denDz , -1);
>> step(sys,60);
>> grid

Figure 10: Step response in digital format

3. Discussion of the results

The method of incineration is suitable, easy to apply, cheap, and more practical. It can be controlled using the continuous control system and it can be provided with an absorption column in which the absorbent is water which is abundant and available. The adjustable parameters and stability of the continuous system can be easily obtained using MATLAB software. Continuous control is recommended as it can stand the conditions of the ambient at Gezira areas. The stability characteristics of a digital loop do not depend only on the controller parameters (kc, i, d) but also on the sampling period (T). A discrete system is stable if all of the roots of its characteristic equation lie inside or on a unit circle in the complex plane.

4. Recommendation

It is recommended that the control should be changed to a discrete system, it is also recommended to investigate the feasibility of producing sugar from biomass for biofuel, furfural and ethanol products.

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