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AN ASSESSMENT OF RENEWABLE ENERGY POTENTIALS IN NIGERIA USING BIOGAS

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ABSTRACT

The economic development of any nation is dependent on its electrical power supply and Nigeria is a country in dire need of industrial development and its attendant economic growth. The availability of Energy is a vital part of any socio-economic structure; it is also a vital part of political, social and economic growth in Nigeria. Insufficient energy supply causes setbacks in socio-economic growth and affects the standard of living in Nigeria, both in different settlements including urban and rural. Improved energy supply means to improve standard of living which can increase food production and storage, industrial development, improve transportation system, and improvement in health service. This research work analysed the current power supply situation in Ikole-Ekiti's and its shortcomings as well as the potential of it being catered to, using biomass power generation. This study was mainly focused on the possibility of using biomass as a source of energy to generate electricity in Ikole-Ekiti. Result from the study shows that an approximate of 41TWh of energy will be generated per year from biomass waste of 56.3 million tonnes. It was also revealed that a total of 1.3TWh of energy can as well be generated per year from wood waste produced by lumber industries of 1.8 million tonnes annually, there by making it feasible and a potential for power generation in Ikole-Ekiti.

Keyword: Biomass. Biogas, Energy, Ikole-Ekiti, Renewable, Waste.

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1. INTRODUCTION

According to Energy Commission of Nigeria (ECN) 2005, Nigeria consumption of biomass resources annually was estimated to be about 144 million tons. Dasappa (2011) projected Nigeria`s biomass resources, from forest waste and agricultural residues can generate 15,000MW of electricity. There is possibility of generating up to 68,000 GWh annually through one-third of biomass resources from the rural communities in Nigeria (Garba and Kishk, 2014). The largest biomass energy source in Nigeria is from forest waste. Biomass resources have the ability to generate electricity in rural communities in Nigeria without the issue of supply chain; however, there is need for emphasis of the supply chain before adoption in these communities as it determines its cost (IRENA, 2012).The Nigeria population has an estimate of over 178.5 million people, 65% of this population is between the ages of 18 to 45 years and over 40% of the population has access to electrical power supply (World Population Review, 2018). Presently, the national grid did not get to most of the rural communities, and with the current rate of development, it would take years for electricity to reach most rural areas in Nigeria. This makes most Nigerians who live in those communities that do not have access to electricity to sort for alternative source of power supply. And an example of such community isIkole, Ekiti. Therefore, as a matter of fact it is necessity to exploit and establish other energy sources to argument the limitations of power poverty in Nigeria. And luckily Nigeria is a country that has surplus natural resources of renewable energy such as Biomass (Amaize *et al.*, 2016). Renewable energy can be a useful alternative to boost electricity supply in Nigeria. It is economical, efficient and environmentally friendly in areas that is far from the national grid and can improve the overall electricity supply in Nigeria which will enhance the development of agriculture and as well enhance the quality of life. It will create jobs, increase production of goods, services and as well improve social service delivery. The thriving industries in ikoleekiti community are agriculture and lumbering. Some of the saw mills in the community are Olo sawmill, Okejebu, Eleyero sawmill, IIamo and Ara sawmill. Ikole`s community has one of the most fertile land in Ekiti State. Even the first major cattle ranch in Nigeria, the Oke-Ako cattle ranch is located in Ikole. Ikole-Ekiti has immense biomass potential. Sustainable power generation and supply is seemingly unachievable in Nigeria despite the country`s surplus fossil fuel and renewable energy sources by Energy Commission of Nigeria (ECN) 2005. The reasons for this inconceivable problem include high gridlines network loses of around 40% especially in Nigeria, investment imbalance of energy infrastructures (World bank, 2005; Garba and Kishk, 2014) and the electricity generation cost using fossil fuel (FF) sources in the country is in excess of US$ 1,000/kW (Eberhand and Gratwick, 2012). Also there is a high investment cost factor in extending the gridline network to rural communities as they are low income earners, have low capacity utilization and are typically a long distance from generating station, making it unattractive to investors in providing electricity to these communities as the efficiency of a transmission system is determined by the ability of the system to efficiently transmit maximum power from generating stations to load centres (Amaize *et al.*, 2017).Nigerian electricity generation and supply still represents around 4,000MW or less for a population of 178.5 million people despite the privatization of the sector in 2013 (Garba and Kishk, 2015). Electricity accessibility in the country remains at 10% and 34% for rural and urban settlement respectively (Garba and Kishk, 2014). The rural community population represent about two thirds of the whole country population, the implication therefore is that majority of the population have little or no access to power and have to source for alternative means to meet their energy needs (Airoboman*et al.,* 2016). For example, fuel wood and charcoal consumption in the country constitutes over 50 million tons annually (Sambo 2009; Ikeme and Ebohon 2005). This energy deficiency has affected the socio-economic setting of the rural communities, with income typically below US$1.25/day (UNICEF 2011). Biomass energy canderived from four energy sources: garbage, wood waste, landfill gases, and alcohol fuels. Most of the biomass sources still rely on incineration, which is, burning of forest residue such as dead trees, dead tree branches and tree stumps, wood chips and garbage is often used. In the rural community's there is need to have sustainable energy sources and been economical to the resident, renewable energy targets (RETs) was applied in providing sustainable electricity to some rural areas in developing countries. The decentralized RETs has advantage in determining when and where power energy is needed, also helps in mitigating greenhouse gas (GHG) emission and creates more employment especially biomass source (Evans et al., 2010). The most used renewable sources includes photovoltaic source, biomass and mini hydropower systems (Mahapatra and Dasappa 2012).

3. METHODOLOGY

Ikole-Ekiti is a Local Government in Ekiti State, with an area of $321km^2$ and a population of 168,436 (National Census, 2006) and a population of 232,300 (National Population Projection, 2016) which means there are 724 people per square kilometer. The average electricity consumption in Ikole is estimated to be 80kW per annum which goes with the assumption they will be powering Televisions, fridges and freezers etc. which makes their average energy consumption 1.56kWh per day (PHCN, Ikole Local Government 2016). This town with an area of $321km^2$ and a population of 168,436 as at 2006 census and a population of 232,300 (National Population Projection, 2016), with around 16,000 households. An average of two different families of five persons in each household is typical, making its total residential power consumption 24,960kWh per day (PHCN, Ikole LG).

The modelling equation for the bioreactor is

$$\frac{dx_1}{dt} = (\mu - D)x_1 \tag{1}$$

$$\frac{dx_2}{dt} = D(x_{2f} - x_2) - \mu x_1 \tag{2}$$

The following equations terms are defined as referred to state variables are as follows

x_1 = concentration of biomass

x_2 = concentration of substrate

D= rate of dilution and

X_2f = concentration ofsubstrate feed.

The specific growth rate which include:monod and substrate inhibition kinetics are given by the following equations:

Monod

$$\mu = \frac{\mu_{rax} x_2}{K_r + x_2} \tag{3}$$

Substrate Inhibition

$$\mu = \frac{\mu_{rax} x_2}{K_r + x_2 + K_1 x_2^2} \tag{4}$$

We can see from the expression that Monod growth rate is a subset of the substrate inhibition model, if $k_1 = 0$

If the rate of dilution is used as the input that is manipulated, then the dynamic model it gives will not depend on scale. For example, a reactor volume of 2litres flowing at the rate of 0.6litre/hour has the same dynamic behaviour as a reactor volume of 500litres flowing at the rate of 150litres/volume. A small scale either pilot plantor laboratory reactor can be deployed to estimate the performance and the behaviour of a production-scale reactor.

The parameters for the substrate model for this work have the following values:

$\mu_{rax} = 0.53hr^{-1}$

$k_r = 0.12$g/liter

$k_1 = 0.453$ liter/g

$\gamma = 0.4$

Steady-state conditions

For a rate of dilution of 0.3 hr $^{-1}$ we notice that we cannot operate at equilibrium point 1. At this point, reaction will not occur again as a result of the cells have been washed out of the reactor. The outlet concentration of substrate is equal to the inlet substrate with these conditions. Therefore,

The system state-space model matrices are given by the following equations:

$$\dot{x} = Ax + Bu \qquad 5$$

$$A = \begin{pmatrix} \mu - D_S & x_{1_s}\mu_s' \\ \frac{-\mu_s}{\gamma} & -D_s - \frac{\mu_s' x_{1_s}}{\gamma} \end{pmatrix} \qquad 6$$

$$B = \begin{pmatrix} -x_{1_s} \\ x_{2fs} - x_{2_s} \end{pmatrix} \qquad 7$$

Where, D_s is the steady-state dilution rate = 0.3 hr $^{-1}$ (and residence time is 3.33hours),

X_{2fs} is the concentration of thefeed substrate = 4.0g/litres

Partial derivative of the specific growth rate is giving as

$$\mu_s' = \frac{\partial \mu}{\partial x} = \frac{\mu_{\max} k_r}{(k_r + x_2)^2} \qquad 8$$

Whenthe rate of dilution is the input that is manipulated.

Various strategies of control have been deployed to effectively manage the biochemical reactors. One of the control strategies is measuring the concentration of the substrate and manipulating the rate of dilution while the biomass concentration is the measured output and the dilution rate is the manipulation input. Control simulation is carried out using a process that is not linear where the inputs and outputs from the process are in physical variables, while the linear controller design depends on the use of deviation variables. Rate of dilution is assumed to be physically constrained to 0.6 hr $^{-1}$.

Stable Steady-State Operating Point

PID controller was designed to effectively manage the bioreactor at equilibrium point 3 the stable nontrivial point. The steady state initial condition for the simulation is giving as:

$$x(0) = \begin{bmatrix} 1.530163 \\ 0.174593 \end{bmatrix}$$

At this point of operation, the state model is given as:

$$A = \begin{pmatrix} 0 & 0.9056 \\ -0.75 & -2.5640 \end{pmatrix}$$

$$B = \begin{pmatrix} -1.5301 \\ 3.8255 \end{pmatrix}$$

$$C = \begin{pmatrix} 1 & 0 \end{pmatrix}$$

$$D = \begin{pmatrix} 0 \end{pmatrix}$$

Eigen values are -0.3 and -2.2630 respectively. Therefore, the system is stable using a PID controller.

The transfer function of the process is given as:

$$g_p(s) = \frac{-1.5302s - 0.4590}{s^2+2.564s+0.6792}$$

Then transfer function of the process in terms of gain and time constant form, considering pole-zero cancellation, the transfer function is reduced to:

$$g_p(s) = \frac{-0.6758}{0.4417s+1}$$

Where, the residence time is longer than the time constant of 0.4417 hr.

Unstable Steady-State Operating Point

The steady state initial condition is:

$$x(0) = \begin{bmatrix} 0.995103 \\ 1.512243 \end{bmatrix}$$

The state model becomes:

$$A = \begin{bmatrix} 0 & -0.0679 \\ -0.7500 & -0.1302 \end{bmatrix}$$

$$B = \begin{bmatrix} -0.9951 \\ 2.4878 \end{bmatrix}$$

$$C = \begin{bmatrix} 1 & 0 \end{bmatrix}$$

$$D = \begin{bmatrix} 0 \end{bmatrix}$$

The Process transfer function for the PID controller is

$$g_p(s) = \frac{-0.9951s-0.2985}{s^2+0.1302s-0.0509}$$

Then considering the model in terms of gain and time constant, the new transfer functions becomes:

$$g_p(s) = \frac{5.8644}{-5.888s+1}$$

This is the transfer function of the process that has a RHP pole at 0.1698 hr^{-1} which remains constant with the state space model.

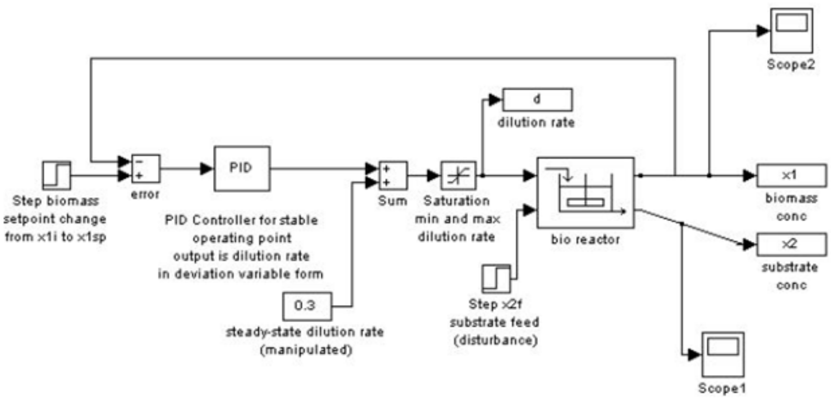

Figure 1.0: The Simulink Model of the Bioreactor.

4. RESULTS AND DISCUSSION

The Simulink model in figure 1.0 is used to run in Matlab. Below shows the graphs of the responses at x1 and x2. We can see also pictorial view with the help of the scope to the two outputs of the bioreactor. The scope1 shows the inputs to the substrate concentrate x2 and scope1 shows the inputs to the biomass concentrate x1, this can be seen in Figure 2.0. The response shows that a small response change varies with lambda. Done by keeping the values of taups, kps, x1i, x2i and x1sp constant. Vary lambda form 10,20 and 30.

Observation with lambda 10

The set point xli = 1.53016; x2i = 1.52; x1sp = 5.

Taups =; kps = 4; lambda = 10.

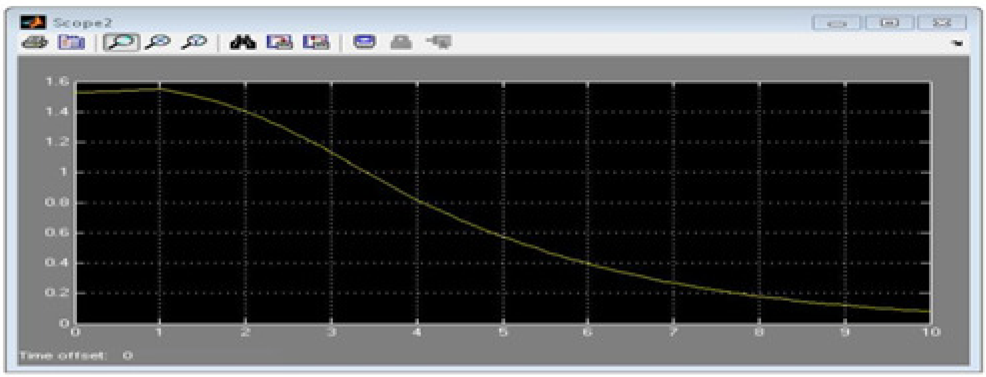

Figure 2.0: small response change at biomass concentrate x1

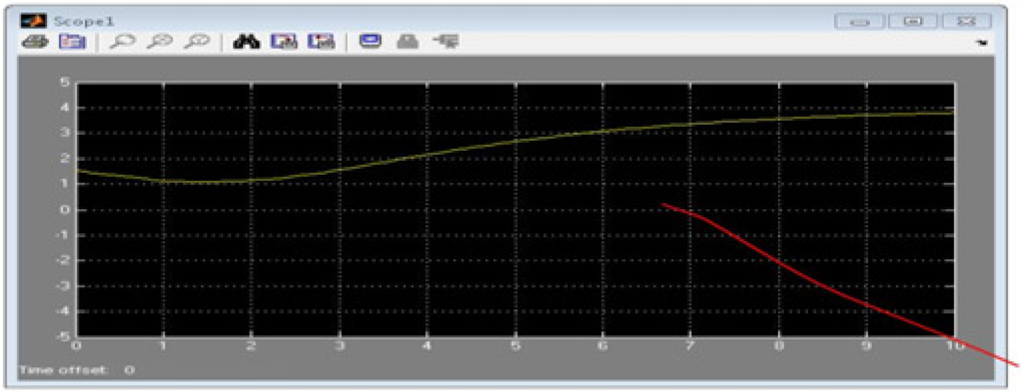

Figure 3.0: Response change at substrate concentrate x2

Observation with lambda 30

The setpoint x1i = 1.53016; x2i = 1.52; x1sp = 5

Taups = 1; kps = 4; lambda = 30

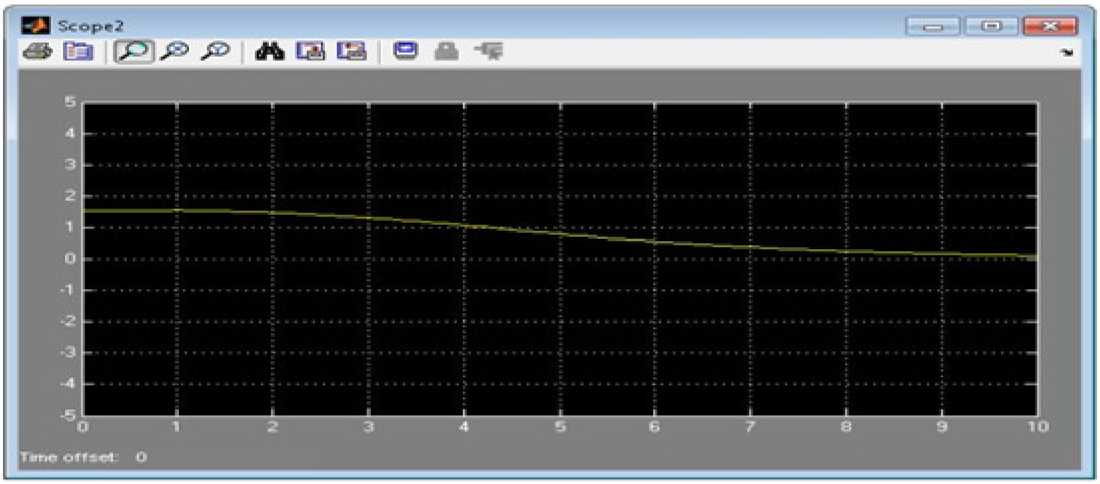

Figure 4.0: Response change at x1 with lambda 30 at x1

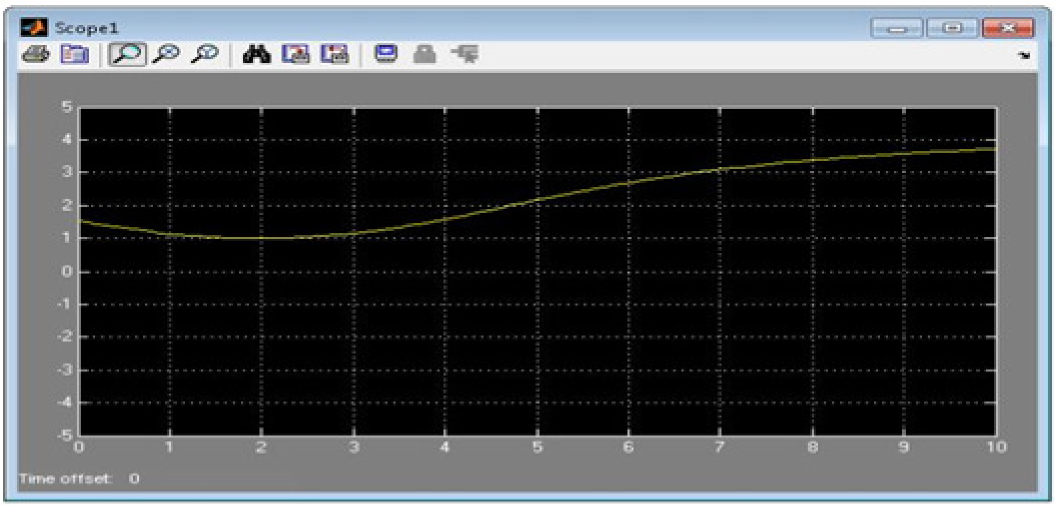

Figure 5.0: Response change at x2 with lambda 30 at x2

The response to a small set point varies with lambda. For a given value of lambda below gives the waveform of how the setpoint variation affects the response.

Observation with x1i = 0.995013 and x2i = 2.0

The x1sp=5.

Taus = 1; 4; lambda = 10

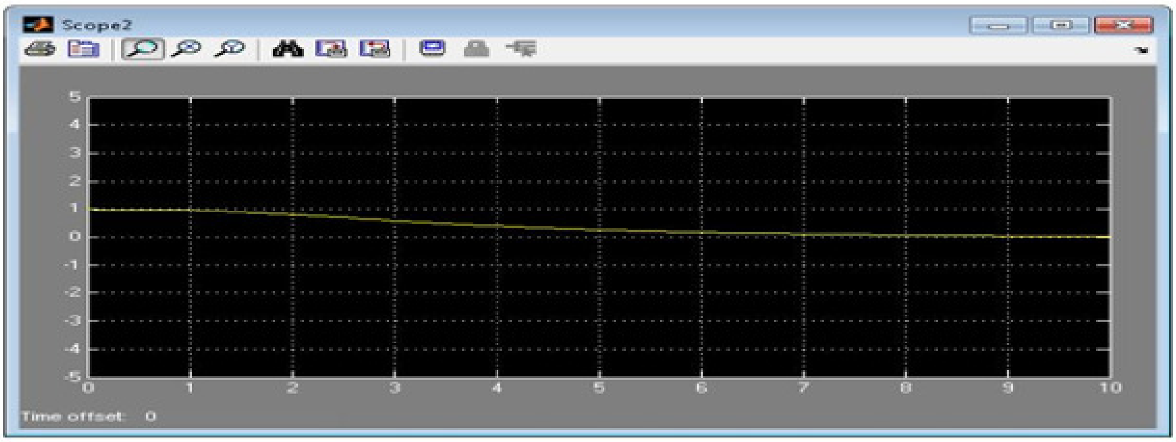

Figure 6.0: Response due to change in setpoint at x1

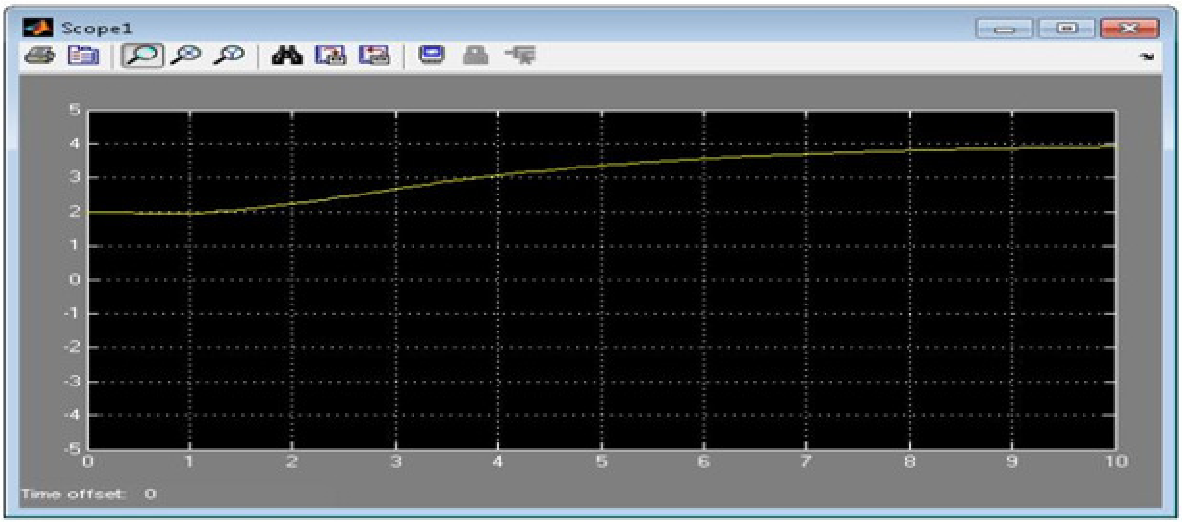

Figure 7.0: Response due to change in setpoint at x2.

Observation with x1i = 2.0 and x2i =30

The x1sp=5.

taups = 1; kps = 4; lambda = 10

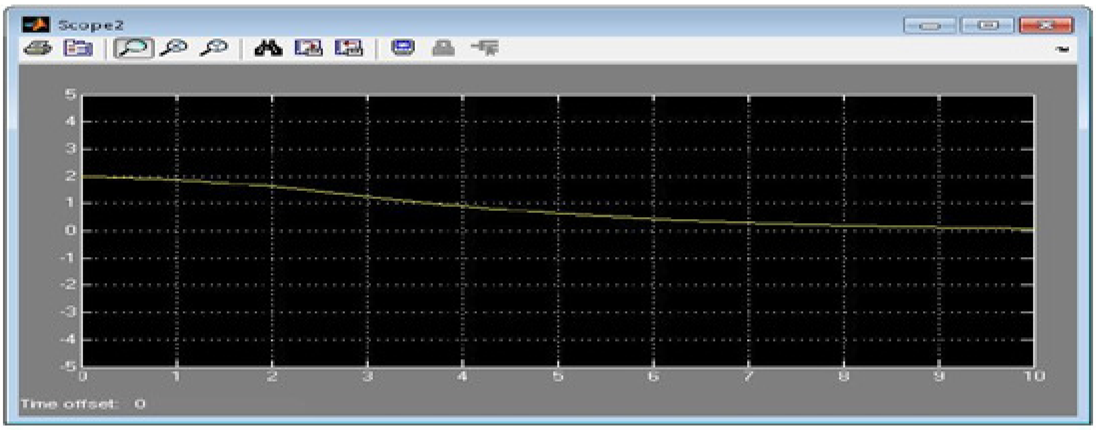

Figure 8.0: Response due to change in set point at x1

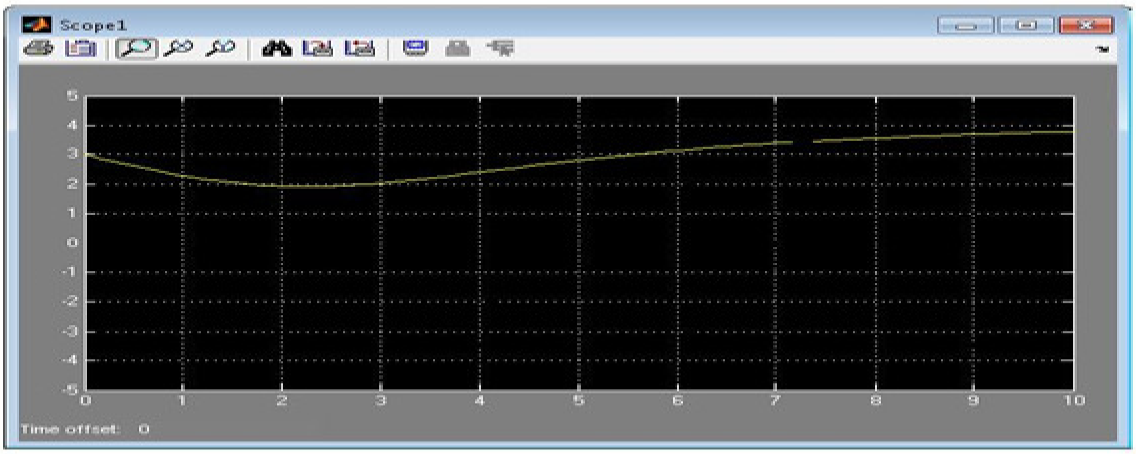

Figure 9.0 Response due to change in set point at x2

5. CONCLUSIONS

In summary, the major aim of this project is to use various biomass power technologies simulations to estimate electric potential of Ikole-Ekiti biomass waste, environmental evaluation and estimating the economic feasibility in building and starting up operation. The paper addresses a power generation system for rural Ikole-Ekiti using Biomass and its potential of its implementation leading to the development of a balanced long term energy supply, while meeting environmental and social objectives in Ikole-Ekiti which also include job creation, improve standard of living and increasing income levels in the agricultural sector.Also the various requirements and methods adopted for the design of this project with the advantages and finally the methods of implementation and testing of the sections of the project is covered.

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