DESIGN AND IMPLEMENTATION OF A DISTRIBUTED SMART-FARM NETWORK

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***Abstract*—There is a growing demand for increased food production globally .Determination of crop varieties which the maximum productivity under specific climatic, irrigation, fertilisation, and soil conditions can easily bridge the gap of food demand globally. Optimum food production can only be achieved by distributed smart farm network techniques. A distributed smart farm network provides a suitable environment for growing crops. With the evolution of WSN and IoT, environment can be automatically controlled and monitored remotely .hierarchical aggregation of data techniques such as LEACH algorithm is used.. LEACH algorithm is efficiency in power utilization. Computational fluid dynamic technique (CFD) is used for optimal placement of sensor nodes. CFD analyses greenhouse indoor temperature distribution .Greenhouse heat flow system is modelled and simulated using Mat lab simscape library block component. Simscape blocks describe physical phenomena by use of building elements.**

Keywords : Computational fluid dynamics (CFD),Internet of Things(IoT),Low Energy Adaptive Clustering Hierarchy(LEACH), Wireless sensor Networks(WSN)

1. INTRODUCTION

Increasing global population has led to increased demand for farm productivity. The United Nations' Food and Agriculture Organization predicts 60% production of food to increase by 2050 to feed global population expected to reach 9.7 billion [1]. In Kenya, Vison 2030 recognizes increased agricultural production a key enabler while the new policy framework announced in March 2018 places national food and nutrition security amongst the four major agenda items [2] .Increased farm productivity can be catalysed by determining crop variety which produces the greatest yield under specific soil, climate, fertilisation, and irrigation conditions. Smart farming involves the use of Information Communication Technologies (ICT) and such as big data analytics and Internet of things (IOT). The data monitored and analysed to identify the crop varieties suitable to a particular farm [3]. WSN and IoT collects, aggregates data from a networks of sensors and communicates the data to cloud for easy remote monitoring.[4].

2.0 LITERATURE REVIEW

Agriculture is one of the best industries in human history due to its ability to produce medicine, food, clothing and energy. Most national economic policies emphasize on technologies increasing agricultural production and the roles of agriculture industry. In 1930s, planes and other heavy agricultural equipment were deployed to increase agricultural productivity.

Smart/precision systems of farming is expected improve farming activities. A few years ago, outdated monolithic and complex systems have been replaced by an emerging sophisticated farm management systems. The management systems are operated via the Internet. The Internet face some shortcomings mostly in handling Internet of things.

The agriculture industry is employing information and communication technologies (ICT) to advance as the other industries. Smart farms are now able to automatically control actuators and monitor the environmental conditions through wireless sensor networks. [5].

J. Lin and C. Liu presented a farm which could be controlled remotely using Smart phones [6]. Akshay *et. al* (2015) presented almost the work as Lin and Liu [7].Yeo and Lee presented system to manage a pig farm by remotely monitoring the environmental using video cameras, humidity temperature and temperature sensors and automatic control control farm air conditioners and humidifiers [8]. Kaewmard *et al* designed a wireless sensor based system to automatically monitor and control agriculture environment by use mobile devices [9].

The world is on technological revolution known as the Internet of Things (IoT). Ashton coined the term IoT in 1999 and represents the advancement of communication and computing where everything worldwide will connected to one another without intervention of human being [11]. Advances in ICT such as wireless communication (WIFI, Bluetooth and zigbee)[12], identification systems (RFID), cellular networks will result to IOT [13] Recently, adoption of IoT-related technology trends, has increased agricultural productivity [14]

Transition to grarian lifestyle has resulted to technological advancements in agriculture to greater yields of crop production. [15]

3.0 GREENHOUSE STRUCTURE, DESIGN AND ANALYSIS

Greenhouses control environments for optimum growth of plants .The greenhouse take into considerations outdoor conditions such as wind direction , temperature, wind speed humidity precipitations and solar radiation such as rain and hailstorms .when designing and erecting a greenhouse structure one must consider; greenhouse orientation, drainage structure, location, foundation, site selection, flooring, ventilation glazing materials. The angle of greenhouse orientation determines the amount of light entering it. According to Dragievi research, angle of incidence of sunrays affects light transmission inside the greenhouse.0^0 translates to 97% light transmission and 45^0 to 95% light transmission. The orientation takes greenhouse dimensions as the reference .The greenhouse longer part must be parallel to East –west direction [16].

4.0 GREENHOUSE SIMSCAPE MODELLING

Greenhouse heat flow system is modelled using Matlab simscape library block components. Modelling and simulation form substitutes for physical experimentation, in which software is used to calculate the results of some physical phenomenon thus saving on time and cost. The development of greenhouse dynamic models by analytical approach is difficulty and a complex process. Simscape building blocks describe a physical phenomenon. The simscape lines connecting blocks are used transmission of heat energy. A greenhouse heat flow models is developed with the simscape blocks through a physical network approach [17].

A greenhouse is divided into two homogenous parts such as cover and internal greenhouse air. The cover separates outdoor environment from indoor one [18].The internal air is greatly influenced by external temperatures. The evolution of climate inside the greenhouse is as a result of greenhouse parts[19]. The greenhouse heat transfer by longwave radiation, shortwave radiation, convection thermal mass and conduction process as shown below

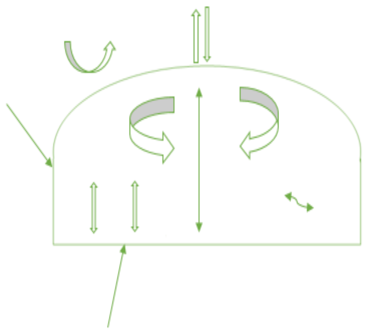
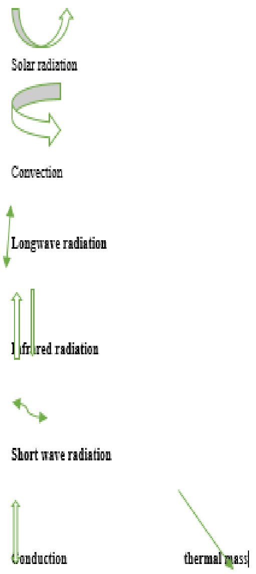


Figure 1 heat transfer



4.1 Heat source

During simulation, sun radiation is considered as the only source of heat in greenhouse model. Analytical approach is used in modelling of heat source. The radiation through the greenhouse side walls and roof affect indoor temperatures such as frame and floor temperatures. The solar radiation fraction transmitted to floor is p while that transmitted air inside the model is (1-p).The heat fluxes is defined by the following equations : [20]

$q_{s.int}=(1-p)I.A_w$ (1)

$q_{s.floor}=p.I.A_w$ (2)

The greenhouse absorbed radiation Q_{GRin} is calculated by equation shown below:

$Q_{GRin} = c \cdot (1 - g) \cdot Q_{GRout}$ (3)

Where c is the polythene paper radiation transmittance , g is the ground surface solar radiation reflectance (dimensionless), and Q_{GRout} is the global radiation outside (W m^2).

The infiltration and ventilation heat loss Q_{iv} was calculated using the equation shown below:

$Q_{IV} = L \cdot E + qv \cdot Cp \cdot (Tin - Tout)$ (4)

where L is the water latent heat of vaporization (J kg^{-1}), E is the greenhouse rate of evapotranspiration (kg m^{-2} s^{-1}), qv is the rate of ventilation (m^3 m^{-2} s^{-1}), C_p is the moist air specific heat (J kg^{-1} K^{-1}), and ($T_{in} - T_{out}$) is the indoor and outdoor temperature difference.

4.2 Greenhouse Simscape Model

The greenhouse Sims cape model is defined by floor, inlet and outlet vents and exterior part of the roof and interior of the roof .greenhouse heat flow exchanges roof, walls, inlet and outlet vents. Each path is modelled as a combination of a thermal elements such as thermal conduction, thermal mass and convection. The simulation calculates greenhouse indoor temperatures

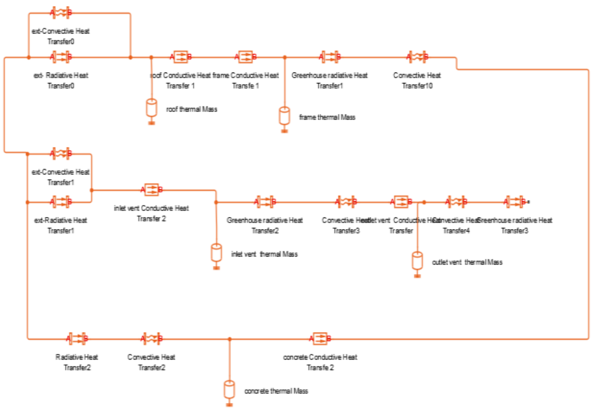


Figure 2 . Simscape model for Greenhouse

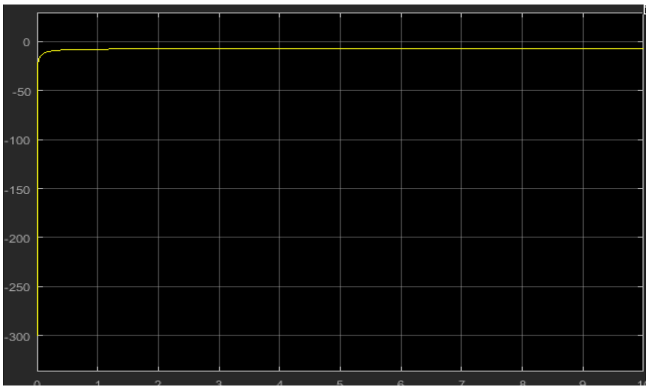


Figure 3 .Roof internal temp

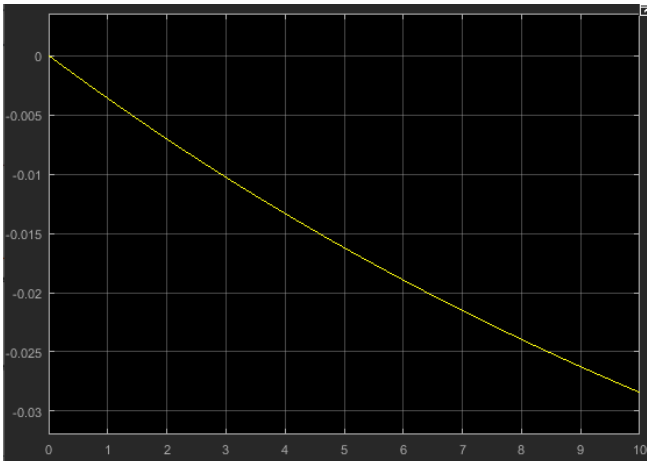


Figure 4 Roof external temperature

5.0 GREENHOUSE SENSORS

The sensors are used to monitor and collect greenhouse information .The sensors can be mounted/placed on greenhouse walls and post or in soil depending on the greenhouse parameter to be monitored. The sensors network can be wireless or wired. Wired sensors are placed away from the output node .Wireless sensors distance from the base station depends on the mode of data aggregation architecture.

5.1 CFD temperature distribution and sensor placement

The CFD simulates distribution of greenhouse indoor temperature. During simulation, the continuity, momentum, k-epsilon and energy equations are considered. The finite volume method (FVM) is a CFD code used to discretize the partial differential equations. CFD simulation and results predicts correctly greenhouse climate. CFD analysis helps in optimal placement of sensors [21]. During simulation, the fluid domain is assumed to be incompressible, turbulent and in steady state. Greenhouse indoor and outdoor temperature conditions through the greenhouse roof made of polyethylene were considered in the top greenhouse wall outside and two side walls as shown below. For the floor, constant temperatures were considered.

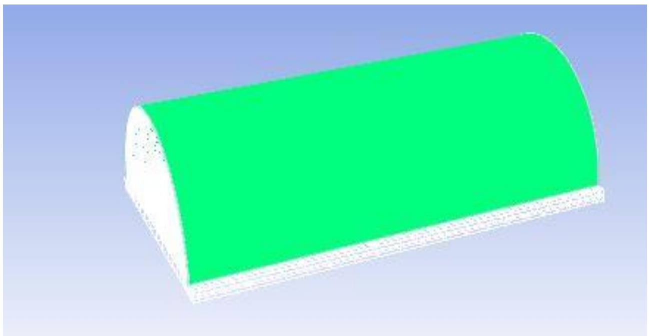


Figure 4 Greenhouse roof

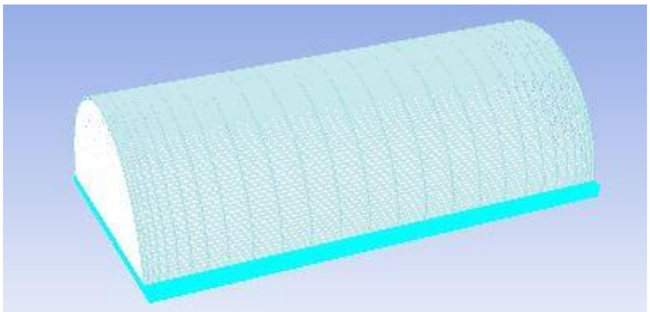


Figure 5 Greenhouse floor

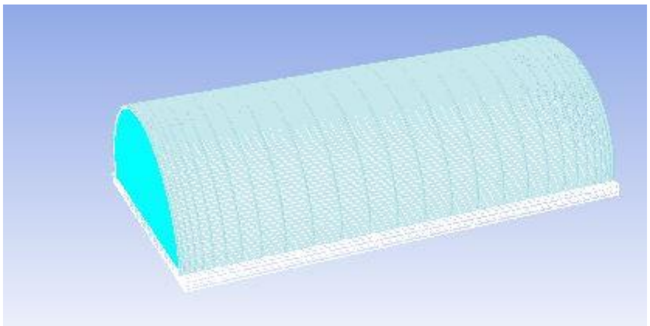


Figure 6 Greenhouse wall A

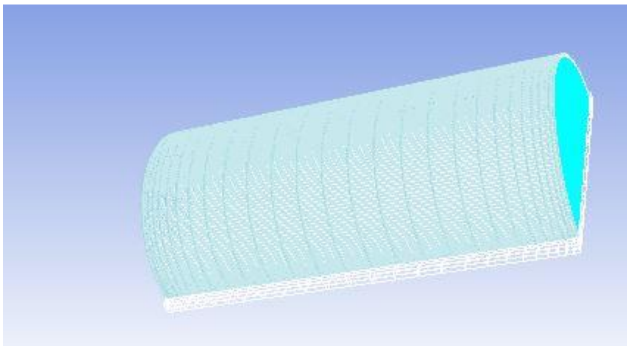


Figure 7 Greenhouse wall

Table 1

Properties of fluid domain

properties	Unit Value
Density kg/m^3	1.0885
Thermal conductivity W/m.K	0.0279
Specific heat J/kg.K	1045.887
Dynamic viscosity Pa.s	1.978×10^{-5}

Table 2

Greenhouse specifications

Type	Parameter	Unit Value
Circular greenhouse	Length (m)	16
	Width(m),	6.4
	Height(m)	3.2
Greenhouse polyethylene roof	Density (kg/m3)	915
	Cp (specific heat) (J/kg K)	1900
	Thermal conductivity (W/m K)	0.33

The structure meshing was done to find number and size of cells suitable for this analysis. Meshing is a key part of the quality and convergence of the solutions. A mixed mesh between tetrahedral and hexahedral elements was used, generating a mesh with a total number of nodes of 152090 and 405077 element.

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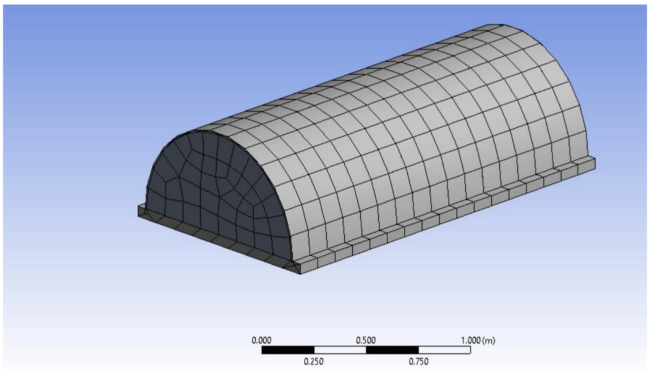

Figure 8 Meshed greenhouse

The model indoor temperature was analyzed and average temperature in the cross-section planes was as shown below .Each layer indicates different average temperature .The optimal placement of sensors was based on planes and average temperature. The model was divided into three XY and YZ planes .the three XY planes locate at 4 m , 8m and 12 m. the YZ plane locate at 0.8 m, 1.6m and 2.4 m. Each YZ plane had 6 sensors resulting to 18 virtual sensors placed optimally in the greenhouse. Sensors were not deployed near the model walls as the spots could easily affect indoor environment.

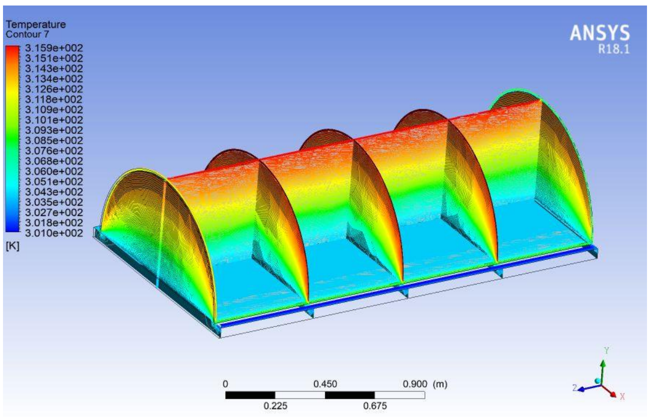

Figure 9 Greenhouse XY and YZ planed temperature distribution

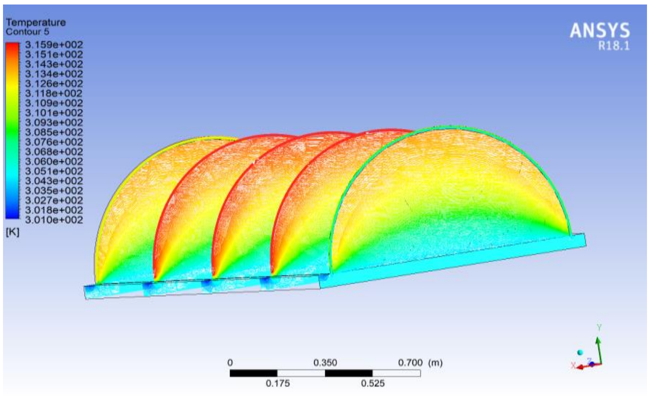

Figure 10 Greenhouse heat distribution

Greenhouse sensor distribution

Type	Parameter	Unit Value
Circular greenhouse	Length (m)	16
	Width(m),	6.4
	Height(m)	3.2
Cover of polyethylene	Density (kg/m3)	915
	Cp (specific heat) (J/kg K)	1900
	Thermal conductivity (W/m K)	0.33

Table 3: Greenhouse sensor distribution

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No.	Type of sensor	Coordinates (m) X, Y, Z (m)	No.	Type of sensor	Coordinates X, Y, Z (m)
1	virtual	4, 0.8, 0.8	10	virtual	8, 1.6, 1.6
2	virtual	4, 0.8, 1.6	11	virtual	8, 1.6, 2.4
3	virtual	4, 0.8, 2.4	12	virtual	8, 2.4, 1.6
3	virtual	4, 1.6, 0.8	13	virtual	12,0.8 ,0.8
4	virtual	4, 1.6, 1.6	14	virtual	12, 0.8, 1.6
5	virtual	4, 2.4, 1.6	15	virtual	12, 0.8, 2.4
6	virtual	8, 0.8, 0.8	16	virtual	12, 1.6, 1.6
8	virtual	8, 0.8, 1.6	17	virtual	12, 1.6, 2.4
9	virtual	8, 0.8, 2.4	18	virtual	12, 2.4, 1.6

The CFD energy k ,standard k-epsilon curve was as shown below.

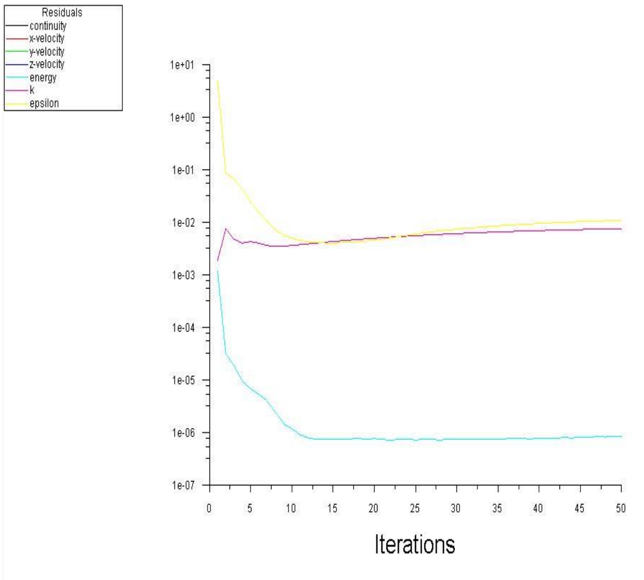

Figure 11. velocity ,momentum and energy distribution curve

1. 5.1 Greenhouse Environmental Monitoring Systems architecture

The data of the greenhouse readings are aggregated and transmitted wirelessly from routing nodes to the sink node (base station) .The messages pass through multiple nodes to reach the base station. The architecture has three tiers; wireless sensor network structure, data transmission base station to cloud interface. The base station is equipped with fuzzy logic to automatically open and close the vents depending on the greenhouse temperature

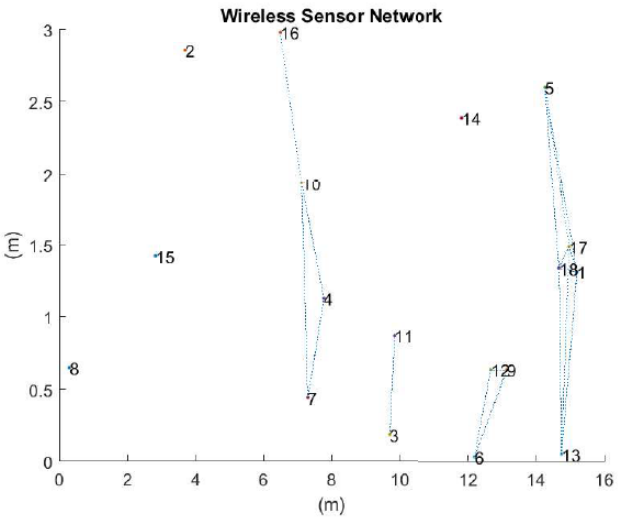

Figure 15. Distributed sensor communication with 18 nodes

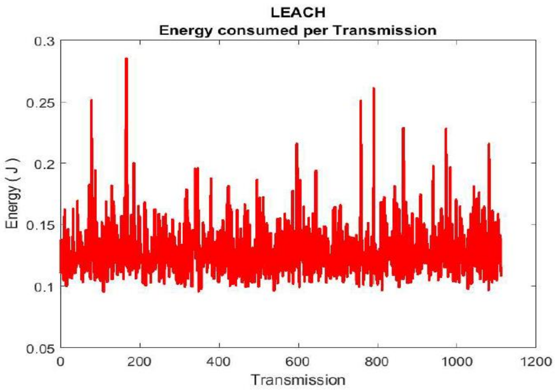

Figure 13 .Energy consumed per transmission

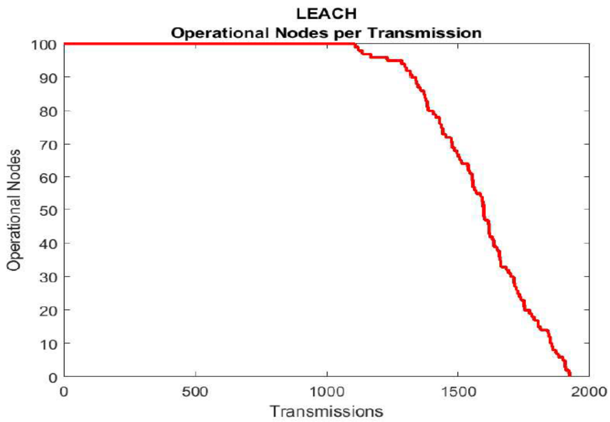

Figure 14. Operational Nodes per transmission

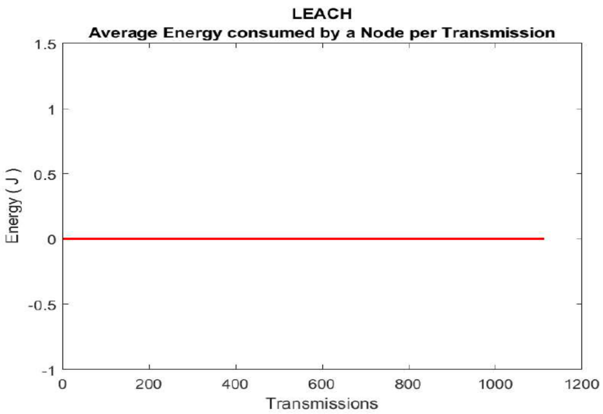

Figure 15 Average energy consumed by a Node per transmission

6.0 CONCLUSION AND FUTURE WORK

The simscape modeling presented a dynamic model of an agricultural greenhouse in order to predict the heat floor using Matlab/Simulink environment. The CFD modeling predicted air temperature and optimal sensor placement using ANYSIS software. The number of sensors placed in XY and YZ was found to be 18 virtual sensors using computation fluid dynamics techniques. The Mat lab Simulink presented a dynamic model of LEACH in order to predict the real time sensor communication environment. The simulation results showed that the twenty sensor nodes die after 1100 transmissions. Control of indoor temperatures results to control air moisture and as well as carbon iv oxide gas. The inlet vent allows inlet of cold air rich carbon Iv oxide gas while outlet vent allows expulsion of hot air. For optimum greenhouse production, camera and nutrition sensors need to be installed to monitor crops pest and disease as well soil PH.

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