DEVELOPMENT OF PARABOLIC SOLAR THERMAL CONTROL SYSTEM FOR INDOOR SOLAR COOKER

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ABSTRACT

Renewable energy, specifically solar thermal harvesting is the world's current focus, proven technically and economically important for home and industrial uses. Tanzanians make struggle for fossils and electricity which they barely can afford and threat to environment. However, overheating of the parabolic solar concentrator caused by intensity of solar irradiances, may destroy the concentrator, house burning and threatening the livelihood. A good number of researches partially addressed overheating with less significant reason. These researches put much effort on heat optimization, limited to industrial consumptions only. To solve this problem, we have established and simulated parabolic dish, temperature control circuit and solar motion tracking and dish control circuits aiming at harvesting sufficient solar energy and control heat by focusing and defocusing the dish to the required energy limits. The experimental results were compared between the current model and existing models. This model shows higher performance on solar energy harvests and heat intensity control mechanism. The significance was to help low income earners by consuming free solar energy instead of paying for charcoal, firewood and electric bills which are too expensive to afford for many Tanzanians. By so doing we also conserve our environment.

Keywords: Parabolic, Thermal concentrator, Thermal control, solar cooker.

1.0 INTRODUCTION

Renewable energy harvesting is the world's current focus, proven technically and economically important. Worldwide supplies from renewable (such as solar, thermal, photovoltaic, wind, hydro, bio fuels, wave, tidal, ocean and geothermal sources) are essential components of every nation's energy strategy and necessary concerns for the energy affordability, environment and sustainability (Demirbaş, 2006).

Solar energy is the most abundant and renewable form of energy compared to other counterparts such as wind-power, fossil, hydro-power and biomass (http://www.scearthconnection.org, 2017). It's cheap, one can literally find it anywhere during the daytime, and it can be used for a variety of purposes. Sunlight can be used for heating and lighting homes and buildings, for generating electricity, and more. It does not require a huge operating area in order to produce large amounts of energy. Unlikely other forms such as; hydro-power plants, windmills take up a lot of space, which limits the usage of wind power on a global scale.

In Tanzania, fossil fuels, charcoal and firewood have always been a main source of energy throughout the years (Barry, 2011). But since they can't be replenished and can do the environment harm, renewable sources of energy are slowly taking their place.

Renewable energy is paving the way for an environmentally safer means of producing power and electricity. While the other types of energy do have their own advantages and disadvantages, solar energy definitely stands out. Given the state our planet is in, solar energy is definitely the best choice when it comes to creating new technologies and ways to save our planet.

Parabolic solar thermal concentrating system is an optical system that concentrates solar energy by converting it into usable energy (Barry, 2011). Considering economic status of most Tanzanian citizens, solar concentrating systems should be designed basing on energy-efficiency, cost effectiveness and affordability. Currently, most Tanzanians consume fossil energy such as firewood and charcoal for domestic use, especially for indoor cookery. Unfortunately, the use of firewood and charcoal releases huge amount of greenhouse gases which have adverse consequence on the environment. Therefore, alternative sources of energy are inevitable to meet future energy demand and sustainable growth of mankind. This study proposes a parabolic solar thermal concentrator control system for in-door cooker.

A parabolic solar concentrator uses solar radiations as free and efficient source of energy. This may be the best option source of energy for many Tanzanian households, particularly, for the low-income earners who cannot afford to pay for other sources of energy. The indoor solar cooker from the parabolic solar thermal concentrator can be the best substitute, as it is a clean energy production, thus serving best in protecting the environment from greenhouse gases pollutants.

However, overheating of a parabolic solar thermal system caused by high intensity of temperature harvested from solar radiation may cause serious damage to the solar cooker and even be life threatening, careless in operation of the parabolic solar thermal collector households may result in house fires or even loss of life, thus one must familiarize oneself with the operation guidelines.

There has been no simple temperature control mechanism for parabolic solar cookers like those seen in electric or gas heaters. This is due to the fact that the energy source is optical in nature. The user needs to manually turn the parabolic dish away from the sun radiation in order to avoid an overcook or food burn. This manual operation process may put the household life in danger if crosses along the focal point of the solar collector. This necessitates the invention of a temperature control mechanism. Thus; this study focuses on filling this gap, by designing a reliable thermal influx controlled parabolic trough solar cooker using solar concentrator. The study addresses the overheating of the parabolic trough, which is a detrimental factor causing many Tanzanian households to intentionally avoid the use of solar cookers.

The study aims to develop a temperature monitoring and control mechanism for a parabolic solar thermal concentrator for indoor solar cookers. The study has focused on the following specific objectives:

i. To identify the possible technical causes of overheating and/or under heating of the parabolic trough heat concentrators. Linear correlation and multiple regressions were performed on the reviewed data to identify which parameter could have been the most influential factor towards solar energy harvest.

ii. To design the temperature, solar motion control circuit and parabolic dish of proposed solar concentrator. We set up all tools and measurements related to each component, then

experimentation was performed form each proposed and existing models, the results where then compared and draw conclusion based on the results.

iii. To determine the relationship between attained temperature and the tilting angle of the parabolic solar concentrator as it withdraw away from right angle degrees of solar concentrator to the diminishing sine of solid angle. We tested various technical parameters as inputs towards solar insolation production.

iv. To integrate up circuit components, parabolic trough, temperature, tilting angle sensors and firmware/algorithm to form a single system. The integration was made by combining up all essential components into a complete parabolic solar concentrator.

The study intends to focus on domestic and community aspect of solar cooker, by discussing the technical aspect and details of designing solar cooker systems, such as parabolic trough design, circuit design, microcontroller programming and sensors integration.

2.0 MATERIALS AND METHODS

2.1 Parabolic Solar Thermal Concentrator

A parabolic solar thermal concentrating system was designed to concentrate solar irradiance for conversion into thermal forms of usable energy. It collects direct solar irradiance from a collection field and concentrates it to a smaller receiver area. At a particular thermal gradient, the heat conveyed from the parabolic solar concentrator to the indoor solar cooker via a well-designed thermal fluid tube (heat transfer medium).

Through the tracking system, heat sensor and angle sensors will be installed to let the microcontroller trigger the parabolic trough direction to or far away from the directly hitting sun radiation, depending on the temperature required by the facility. The thermal fluid tube (heat exchange system) will regularly be sending back and forth the heat between the parabolic trough and the solar cooker, as a means of regulating thermal heat alongside the heat transfer system.

The programmable electronic circuit and microcontroller after receiving heat level and angle from the sensors eventually respond according to the instructions written into the controller which will make the parabolic trough respond accordingly. A parabolic solar thermal concentrator has sun tracking system to follow the sun’s movement. As the parabolic dish tilts, according to the sun motion, the intensity of solar radiation falling on the surface increases, which result into high intensity of heat harvest. The abnormal rise in heat may lead to overheating and damaging of the solar cooker and even course danger to the household.

A solar concentrating system consists mainly of an absorber, a receiver and a sun tracker. The concentrator, which is usually a parabolic dish, has to track to the sun position throughout the day, and even throughout the year. Moreover, the initial position of the tracking system should be calibrated to the particular position on the Earth's surface due to latitude variation (Ramírez, et al. 2011).The tilting angle of the parabolic trough influences the number of solar radiations and the intensity of heat at the focal point of the trough.

2.2 Parabolic Trough System Design

The parabolic dish was designed using Solid works 2016 Solid-Works is a powerful computer-aided design (CAD) and computer –aided engineering (CAE) computer program used to design civil and mechanical components of various shapes. Various components of the parabolic dish were designed using this program.

After doing preliminary observation we found out that, solar thermal harvest can be influenced by many factors such as geo, seasonal and metrological. In detail we name them as solar angle, wetness, Clearness, temperature and wind-speed. Therefore, in order to solve the addressed problems raised by overheating of the parabolic solar thermal concentrator, we need to first identify all possible courses of the concentrator overheating as the predictor factors and use them as input against the prediction (solar insolation).

Sample of the prediction parameters were drawn from the potential sites of geo and metrological information agencies belonging to the category of Tanzania Metrological Authority (TMA) and National Aeronautics and Space Administration (NASA), Electronics, solar and embedded systems professions and also from testing (experimentation) the existing parabolic solar concentrators systems including various related publications.

For each factor we were first interested with the level of linear relationship between the parameter and the solar intensity. To establish this, for each parameter we run separate linear correlation analysis-based on equation (1).

$$\mathbf{r} = \frac{\sum_{i=1}^{n}(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i-\bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i-\bar{y})^2}} \quad (1)$$

Where

$\boldsymbol{n}$ Means the sample size

X_i ` Means sample parameters used to determine intensity of insolation

Y_i Means the predicted intensity of solar insolation

Where a means partial correlation coefficient
c is the initial or constant value.

Usually the correlation range of r is supposed to fall under [-1, 1]. Value of 1 means a perfect positive relationship and value of 0 means no relationship at all and the value of -1 means perfect negative relationship.

The factors with good linear relationship were further subjected to a simple and multiple regression models to determine the nature of the relationship with the solar intensity as the predicted variable. The multiple regression relationship was determined by the following regression equation (2)

$$\mathrm{Y} = \sum_{i=0}^{n} a_i x_i + \boldsymbol{b}_0 \quad (2)$$

Where by

$\boldsymbol{a_i}$ = Partial regression coefficients for variables $\boldsymbol{x}_i \ldots . \boldsymbol{x}_n$

$\boldsymbol{Y}$=solar insolation

$\boldsymbol{a}_1$ = Wet days, d

$\boldsymbol{a}_2$ = Clearness, 0 - 1

$\boldsymbol{a}_3$ = Temperature, °C

$\boldsymbol{a}_4$ = Wind speed, m/s

$\boldsymbol{a}_5$ = Precipitation, mm

$\boldsymbol{b}_o$ =constant

The regression coefficients for each parameter were observed and concluded into relationship status. The result was considered positive or negative relationship if the significance value P <0.05. And in our case r Square must be r >50%, here the higher the R square the higher the means of relationship between Multiple parameters and Solar insolation. The system development life cycle of the parabolic solar concentrator model is depicted in Figure 1.

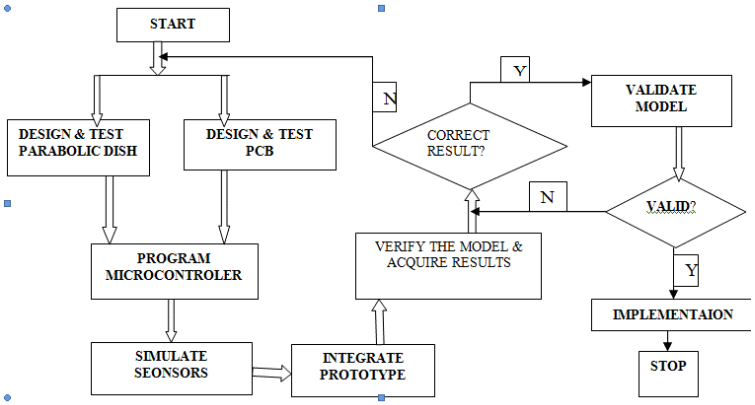


Figure 1: System development life cycle of the parabolic solar concentrator model

2.2.1 Reflector

The reflector of our experimental device consists of a parabolic concentrator of 2.2 meters opening diameter. Its interior surface is covered with a reflecting layer which reflects solar rays on the face of a receiver placed at the focal position of the concentrator. The concentrator is posed on a directional support according to two axes to ensure the follow-up of the sun.

2.2.2 Assumptions

1. The equation for the parabola in U-shaped coordinates is:

$$Z = r^2 / 4f \quad (3)$$

r=the diameter of the opening parabolic surface.

z=Axial distance, (m)

f=the focal distance of the parabola.

2. The surface of this parabola is given by:

$$S = (8\pi/3)f^2\{[1 + (d/4f)^2]^{3/2} - 1\} \quad (4)$$

S=the surface area of the parabola.
f=the focal distance of the parabola.
d= the diameter of the opening parabolic surface.
3. The cross-section of the opening parabola is:
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$$S_0 = \pi d^2/4 \quad (5)$$

S_0=Parabola area, (m2)
d= the diameter of the opening parabolic surface.

4. The focal distance is given by the following expression:

$$f = d^2/16h \quad (6)$$

Where,
h= the depth of the dish.
d= the diameter of the opening parabolic surface.
f=the focal distance of the parabola.
The characteristics of the solar concentrator is depicted in table 1.

2.2.3 Receiver

The heat absorber is located at the focal point of solar irradiance. The U-shaped parabolic trough is used to permit high collection of heat intensity and low heat loss due to wind interference. The concentrator is oriented in front of sun according to two freedom degrees while tracking the solar movement. Solar angle and declination angle of solar radiations were used to determine the harvested solar thermal intensity. The first jack ensures the follow up of the solar angle. The second one permits movement of the concentrator according to declination angle. This command system permitted us to obtain a U-shape of sunspot as shown in Figure 2.

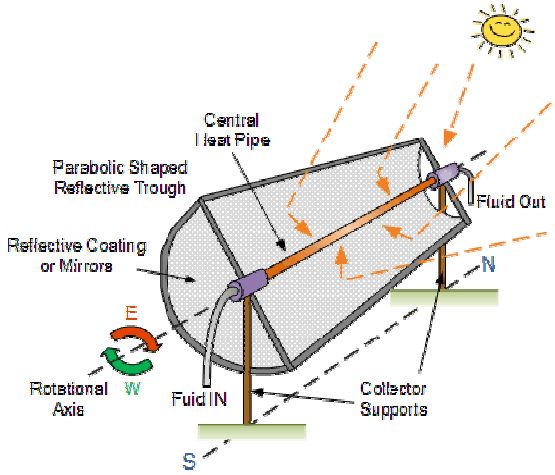


Figure 2: Solar energy absorption trough

The advantages of this type of tracking mode is that very little collector adjustment is required during the day resulting in the solar trough always facing the sun at noon time, but the collector performance early in the morning or late in the afternoon is greatly reduced due to the large incidence angles of the trough. The receivers are covered with a thin coat of black paint, with an effective absorption coefficient and are located in the focal zone of the parabola. The geometrical concentration of this model is:

$$C_g = S_o / S_a \quad (7)$$

S_o =Parabola area, (m^2)

S_a =receiver area (m^2)

C_g =Geometrical concentration coefficient

$$\Phi_{incid} = \varphi_s / \cos(\delta) \quad (8)$$

Φ_{incid} =direct solar flux

$\cos(\delta)$=angle declination,

φ_s =heat on the surface of the dish.

The dish was designed in a U-shape figure, so that it should be able to fetch enough solar irradiance and concentrate them on a long heat absorber, the U-shape ensures maximum harvest of solar insolation. The dish was designed to 90 degrees solid angle to ensure collecting enough heat from solar irradiance.

2.3 Temperature Sensor Control Circuit Design

This research requires designing a parabolic solar concentrator to operate at extreme temperatures of above 1000°C. Therefore, we had to select thermocouple type K as the suitable sensor for the proposed solar concentrator. A thermocouple produces a temperature-dependent voltage, small signals, often microvolts in magnitude, as a result of the thermoelectric effect, and this voltage can be interpreted to measure temperature. Precise measurements of this signal require an amplifier with low input offset voltage and with care taken to avoid thermal emfs from self-heating within the voltmeter itself. If the thermocouple wire has a high resistance for some reason (poor contact at junctions, or very thin wires used for fast thermal response), the measuring instrument should have high input impedance to prevent an offset in the measured voltage. A useful feature in thermocouple instrumentation will simultaneously measure resistance and detect faulty connections in the wiring or at thermocouple junctions.

With respect to the effects of temperature change on dissimilar metals, measurable voltages are produced. In order to make the measurements as accurate as possible, the amplifier circuit is needed with regard to the thermocouple selected; in this case we have selected thermal couple Type K. Different thermocouples sensors have a different temperature coefficient meaning that they will generate different amounts of voltage for the same change in temperature, usually specified in volts per degree of Celsius (v/◦C).Knowing the temperature coefficient of a sensor is only half the equation, we also need to nail down the zero point, meaning that we establish a calibrated reference point.

There are different approaches to follow into zeroing out and measure the change in volts per degree C, such as applying a known temperature such as immersing the sensor in ice water would be a simple if inconvenient way to establish a known reference temperature.

In this case, we are using a Cold Junction Compensator (CJC), which is the LT1025, a chip made to not only replicate the different temperature coefficients of the various thermocouples, but also give us a pretty reasonable calibration. CJC acts as another thermocouple or thermometer and changes the voltage as seen by the thermocouple, which is at room temperature in our case, and also corrects for some other non-linearity. With the thermocouple being driven by the CJC the output of the thermocouple is then fairly linear and fairly calibrated.

The signals as generated by the CJC as a response form the voltages from the thermocouple is need to be amplified, ready for being processed by the microcontroller. A keen consideration has been made with respect to power consumption and accuracy of the amplifier during selection, whereas the LTC1049 Low Power Zero-Drift Operational Amplifier, which has internal capacitors.

We have set fixed solid angle at 90 degrees, so that the cosine is 1, to be able to have maximum harvest of solar energy intensity. However, by so doing we get another challenge, that is, the more the radiation we get the more the temperature overrides. Therefore, temperature harvest can be higher than the required level. Now, the easiest way to control this temperature is to defocus the parabolic dish away from direct hit of solar radiations. This means we have changed the solid angle from 90 degrees backward to δ angle. Although we set fixed solid angle to get maximum harvest, we move the dish away from solar incidence when the temperature exceeds the required level.

The reasons to reduce heat intensity is that parameters such as heat loss convection, heat conduction due to cooking and radiation level which can be used to remove heat has lower rate than the rate at which heat is produced. Because thermal energy is concentrated at the absorber, we have to remember that solar energy is cumulative in three cases. Since our target is to reduce heat intensity, then our target has specific heat capacity, there has to be something which removes energy from the absorber, therefore if the rate of removal is lower than the rate of incident, then energy is cumulative to higher intensity. That is why we are still experiencing overheating of the parabolic solar concentrator even if heat loss due to convention and conduction exists.

1. Loss due to convection occurs when thermal fluid is when a pump forces is applied to push thermal conductor towards the solar cooker in the kitchen.
2. Loss due to conduction occurs when the thermal fluid goes back to the heat source (solar absorber). Figure 3 shows the fluid flowing from parabolic thermal concentrator to in-door solar cooker and back to the absorber.

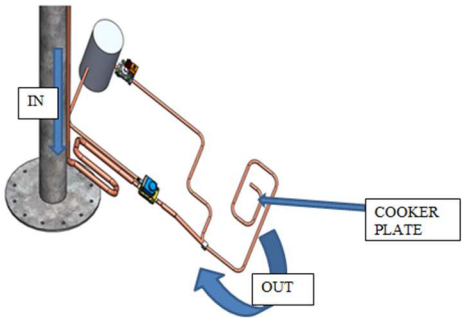


Figure 3: Thermal fluid In and Out.

The aim of this research at this point is not to construct a thermometer but to activate or deactivate a parabolic solar concentrator by tilting it away or towards solar radiations at a particular margin of temperature. Temperature control was finalized by writing the microcontroller with c programming language.

2.3 Solar Motion Control Circuit Design

The parabolic solar concentrator is operating at optimal parameters when they are at the perfect right angle to the sun. In order to archive this, we set the solid angle to 90 degrees fixed at different solar positions. We have two ways of tracking solar radiation.

i. Metrological information. There are cases which happen to reduce solar intensity. These are metrological information (cloud cover, precipitation etc.), so we need to sense the solar angle. So that when there is solar cover, the system needs to remember the particular angle of same dates where solar radiations can be found, and move the dish to that particular angle.

ii. Real time tracking. The constant change in the position of the sun throughout the year has posed quite a big challenge for us as far as solar power harvesting is concerned. A solar tracker is a device for orienting a solar concentrator trough, day lighting reflector or concentrating solar reflector or lens toward the sun. Solar power generation works best when pointed directly at the sun, so a solar tracker can increase the effectiveness of such equipment over any fixed position. The solar parabolic trough is set perpendicular to the sun's rays for maximum energy generation. The parabolic solar concentrator is operating at optimal parameters when they are at the perfect right angle to the sun. In order to archive this, we set the solid angle to 90 degrees fixed at different solar positions.

Development of solar panel tracking system has been ongoing for several years. As the sun moves across the sky during the day, it is advantageous to have the solar panels track the location of the sun, such that the panels are always perpendicular with the position of the sun. Available solar trackers in the market are much costly to integrate with solar panel system. The major components used in our design are:

- Photo resistor
- Microcontroller
- Stepper motor

Figure 4 shows the model of the solar tracker prototype. As illustrated the solar tracker prototype accommodates both degrees of freedom: azimuth and vertical. Note that two LDR sensors module and thus same control algorithm are implemented in both degrees of freedom.

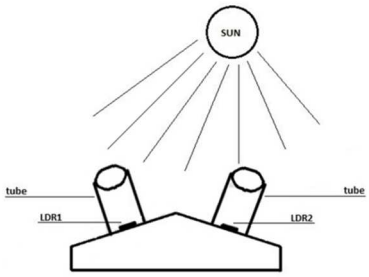


Figure 4: Solar tracking sensors LDR1 and LDR2

For the each of axis, we used two sensor modules. The sensor module which used to vertical axis should be normal to motor of vertical axis. Then that motor can align the vertical axis with sun.

In this prototype another axis is azimuth. Then the sensor module which used to azimuth axis is at normal to another sensor module. Then the motor belongs to that axis aligns azimuth axis with sun. We have installed two sensors separately. And have integrated in to one sensor which can align two axes with sun. The materials used in the construction of the prototype include Perspex 2 mm sheets. The vertical axis was constructed by using Perspex sheets and motor connected to the panel as above figure shows.

Solar tracker control circuit consist power supply, two motor drivers, two light sensors and micro-controller (Atmega 328p). A voltage supply of 12V is applied to the circuit which is then passed through a 5V voltage regulator.

When sensor is normal to the sun, there is no shadow of object on the LDRs. Then, the light intensity on the LDRs is same. Therefore, digital values are also the same. If sensor is not normal to the sun, there should be shadow of object on one of the LDRs. Then, the digital value of the LDR which get dark is less than the digital value of another LDR.

Each LDR have bridge circuit produce analog voltage which proportional to light intensity. That analog voltage connected to the ADC module of Microcontroller. The logic that works on the Microcontroller to get the analog values as inputs and compare two analogue values form LDRs belongs to each sensor and find which LDR is under shadow. Then rotate motors which belongs to each sensor until minimize the difference between two ADC values with an error margin of ±5 points. Simultaneously two motors are rotate according to minimize the difference between two ADC values.

After designing the parabolic trough and circuitry components, the physical integration of the hardware was made possible, considering the source-codes in place for controlling the tilting angle of the parabolic trough and motion towards and away from the sun radiations. The integration was also determined the machine learning intelligence of the solar cooker; machine learning will keep track of previous history of the parabolic trough triangulations in relationship to weather condition and level of temperature maintained during that period of time due to changes in season.

System performance was measured by comparing from the existing systems. Temperature behavior of the local environment was essential parameter during performance examination. The performance was examined using a computer that was linked to the controller being designed, whereas data being collected was forwarded to the computer for computational in comparison with data from other systems. Figure 5 shows the solar thermal data acquisition system from the parabolic dish to the computer system.

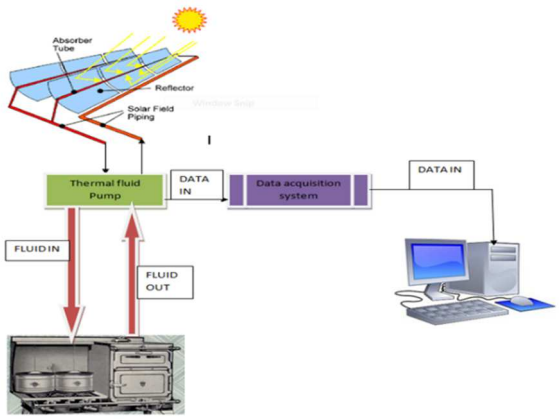


Figure 5: Solar thermal data acquisition system

3.0 RESULTS AND DISCUSSION

To determine the most influencing parameter on solar thermal heat variation, we reviewed geo and metrological data from NASA and TMA. Data involved was solar angle, wind speed, cloud clearness, precipitation, wetness and temperature. By doing so we intended at picking the factor which could have huge impact on solar energy harvesting. We used linear correlation and multiple regressions to determine the significances relationships by collecting coefficient correlation, p-value and standard error for each parameter and in multiple. Then this correlation helped us to pick and use the most influencing factors as inputs to our experimentation and able determine the maximum heat harvest and the measure we can take to control the overheating of the parabolic solar concentrator. In order to archive this specific objective, the metrological, geographical and seasonal data, were taken into consideration as main parameters.

3.1 Results on Solar Angle Determination

Correlation between solar angles and temp during Equinox and Solstice are proportional with higher Temperature satisfaction scores of R= 0.51. This can be considered large effects to Overheating of the parabolic concentrator. Therefore, we consider solar angle as the prediction parameter to solar insolation harvesting by linear correlation addressed by the output linear equations such as, $y = 0.0282x + 30.283$ for maximum temperature and $y = 0.0565x + 20.566$ for minimum temperature harvest during equinox and solstice at the correlation value of R=0.98.

3.2 Correlation Values between Solar Insolation, kWh/m²/day and Wet Days, D, Clearness, 0 – 1, Temperature, °C, Wind Speed, m/s, Precipitation, mm.

The geo information data was collected at TMA workstation in order to determine the relationship to solar insolation harvesting in order to design an effective parabolic solar thermal

control system. The annual prediction data collected from January 2017 to December 2017 in Dar es Salaam are depicted in Table 1.

Table 1: Solar energy and surface metrology per square meter in Dar es Salaam, Tanzania

	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wet days, [d]	9.7	4.3	11.6	13.3	14	5.8	5.9	5.7	5	6.9	8.9	12.3
Clearness, 0 - 1	0.54	0.55	0.52	0.5	0.5	0.54	0.52	0.51	0.55	0.54	0.54	0.55
Temperature, [°C]	26.76	26.89	26.88	26.21	26.33	25.69	25.04	24.83	25.03	25.52	26	26.46
Wind speed, [m/s]	4.33	3.98	4.46	5.67	7.21	7.63	7.47	6.64	5.89	5.9	5.26	4.32
Precipitation, [mm]	70	49	120	130	153	40	26	23	25	49	106	114
Insolation, [kWh/m²/day]	5.79	5.93	5.4	5.2	4.5	4.57	4.52	4.76	5.59	5.67	5.76	5.78

3.3 Results on linear correlation and multiple regression

Multiple correlation method was used for experimentation purpose, where the input values of given data (Wet days, d, Clearness, 0 – 1, Temperature, °C, Wind speed, m/s, Precipitation, mm). After performing multiple correlations, we did multiple regressions to justify the correlation value by determining the significant correlation. The findings show that there is a positive relationship between clearness and solar insolation by the correlation of R = 0.673975771, as analysis results shows in Table 2. It can be concluded that during May and June, July fell to 4.5W/m^2 amount of solar insolation due to cloud covering the sky, which led to insufficient solar irradiance falling on the parabolic trough surface. Therefore, we are able to harvest enough solar insolation on months of October, November, December and January. This means by managing cloudiness and clearness we consider it to be a viable determinant of solar energy insolation. Moreover, the relationship between the rise in temperature is directly proportional to the rise in insolation intensity at the correlation of R=0.463601586.

Therefore, temperature falling over the surface of the parabolic trough is direct proportional to the temperature accumulated over the surroundings due to huge amount of solar radiation recorded at the times when temperature was high. This means the fall and rise in temperature has a big impact to the rise in solar insolation harvest, using linear correlation equation y = 0.628x + 22.622, during November, December and January the solar intensity harvest is likely to rise from 4.57 to 5.78W/m^2 according to temperature on the surroundings and months May, June, July and August had experienced an average fall in insolation to 4.5W/m^2. Similarly, this means that with this positive correlation, temperature can be used as input and predictor parameter to our solar thermal experimentations.

Further, the wind speed and Solar insolation are correlated with negative energy scores of R= -0.896546077 which can be considered a large effects to under heating of the parabolic concentrator as shown in Table 2. The wind behavior can be major obstruction to solar irradiance, as wind tends to resist and converge solar radiations to fall over the parabolic trough. The higher the amount of wind tends to lower the amount of solar insolation on the earth`s surface to negative. If solar radiation is converged at less than 90 or more than 90 degrees on the trough surface we experience less amount of heat harvest and at 90 degrees we experience

maximum heat harvest, this is according to correlation analysis obtained using equation y = -2.1044x + 16.883. The amount of solar insolation harvested at months may, June July and August were less than at months October, November, December and January, due to variation in the amount of wind currents. With this positive correlation, wind can be used as input and predictor parameter to our solar thermal experimentations. We managed to control wind speed by building a U-shaped parabolic dish where the focal point appears below wind abstraction level.

Table 2: Multiple correlation of seasonal values and solar insolation

	Wet days, [d]	***Clearness, 0 - 1***	***Temperature, [°C]***	***Wind speed, [m/s]***	***Precipitation, [mm]***	***Insolation, [kWh/m²/day]***
Wet days, [d]	1					
Clearness, 0 - 1	-0.49746257	1				
Temperature, [°C]	0.538418888	0.098305015	1			
Wind speed, [m/s]	-0.1809724	-0.453277703	-0.70489591	1		
Precipitation, [mm]	0.943336055	-0.409780002	0.652301934	-0.261049474	1	
Insolation, [kWh/m²/day]	-0.03298398	0.673975771	0.463601586	-0.896546077	0.065207635	1

In addition, the precipitation and solar insolation are correlated with positive and lower correlation to solar energy at a scores of R= 0.065207635 which can be considered there is slightly positive impact to the amount of solar insolation due to precipitation. This means precipitation has less significance to the experimentation. The rise in the amount of precipitation contributes to less amount of insolation. The trend in fall of solar insolation are due to increase in precipitation level using correlation equation y = 7.0485x + 33.117; where at months July insolation level fell to 4.52W/m^2 while at months of December the insolation was tested to rise at a range of 5.78W/m^2 maximum. This means that with this less positive correlation, precipitation can rarely be used as input and predictor parameter.

To be able to keep memory of seasonal properties, the parabolic solar concentrator will have to keep track of all monthly and seasonal weather properties in a log file format. This will help the system to automatically adapt new position by recalling the stored log data. Changes in seasonal weather for example during cloud times, the parabolic dish may fail to track the sun, since the sky may not be clear. Failing to track the sun motion, may lead to insufficient solar energy harvest. In this case the program is written to tell the parabolic solar concentrator to read back to the log data, and remember the best solar position it used to track enough solar radiations. The parabolic solar concentrator keeps track date and positions on equinox, solstice and other seasons.

The clearness of the sky contributes to enough solar energy harvest for months such as Feb, Sep and December of 2017 are likely to have clear sky with 0.55 clearness and higher insolation of 5.93, 5.59, 5.78 kWh/m^2 respectively, compared to other months with low insolation results. This means clouds can be a big obstacle to solar radiation to penetrate over to the surface of the earth, which make a low a harvest of solar insolation using a parabolic trough solar concentrator (Figure 6).

Readings from Figure 7 show that temperature the rise can be of great advantage for solar energy harvest, the results in hottest moths such as December, January February and March measuring temperature range of 26.46, 26.76, 26.89 and 26.88 respectively we are able to harvest enough accumulative heat as the graph shows compared to other months falling over 24 temperature range. The increase in wind speed can obstruct with the incoming solar radiation from falling directly on the surface of the parabolic dish, some radiations may not fall under 90 degrees solid angle which may result in shifting the focal point away from the heat absorber/receiver. Also, having focal point height far away from the dish can accelerate wind-speed to have huge impact in obstructing heat to reach the focal point. However, in our case, this is not a big issue since we have designed the dish in a U-shape model in order to minimize wind speed obstruction, where the focal point is designed inside the dish in order to resist from wind crossing along the dish surface. The results show less solar insolation on months such as May, June, July and august due to high wind obstruction over the parabolic dish 7.21, 7.63, 7.47 and 6.64 mm respectively. Wetness and precipitation are addressed as major factors, in months of high precipitation. Wetness shows a decrease in solar insolation harvest months with high rainfall, high humidity and wetness and an increase in solar insolation in months with Low rainfall, low humidity and wetness. Considering the graph in Figure 7, the trend in insolation variation due to wetness and precipitation is demonstrated.

Distance of the sun from the earth's surface is a barrier to harvesting enough solar energy. Variation in seasons caused by the earth's rotation and revolutions may results in situations such as equinox and solstices. Equinox: occurs when the equator passes through the sun disk. Usually twice a year: around 20 March (13:29) and 22 September (23:02) solstice: The sun is overhead twice a year around. 21 Jun (07:24) and 21 Dec (19:28). Normally around these months the earth is near to the sun which makes sufficient solar irradiance to fall over the parabolic dish surface.

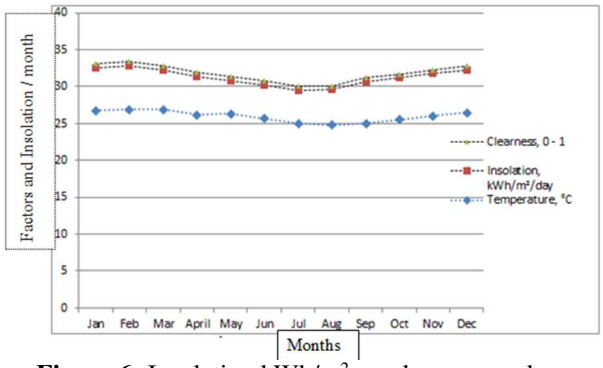


Figure 6: Insolation kWh/m^2 vs. clearness and temperature

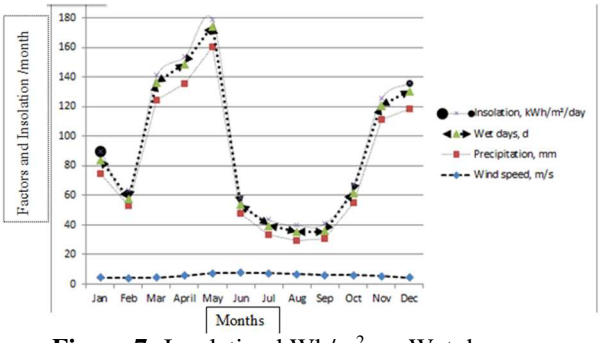


Figure 7: Insolation kWh/m^2 vs. Wet days, Precipitation and Wind speed

4.0 CONCLUSION

This study presents the design and evaluation of a two-axis solar tracking system based on aiming at controlling the intensity of solar energy harvested using parabolic solar concentrator system. Identification of major factors which could be the predictor parameter to solar energy harvest was made by performing linear correlation of each parameter against solar insolation and few of them were identified with large and perfect correlation coefficient such as solar angle, temperature wind speed and clearness. Design and set up of the parabolic solar concentrator were

made effectively and the resulted solar insolation harvest showed a tremendous performance on the proposed model against the results from the existing model.

Using sensor thermocouple type K and Two installed solar motion; the proposed parabolic solar concentrator was able to perfectly track the solar motion and maintain solid angle at 90 degree of the solar irradiances on the parabolic trough. Likewise, in same facility temperature control circuit has been installed to sense and control the amount of solar insolation on the receiver/absorber.

The experimentation set up was effectively performed and the results were collected using digital multimeter and pyrometer for data acquisition and plotting of graphs.

The research experimental results show that temperature was effectively harvested to larger amount compared to existing model and the control mechanism of the temperature under a particular maxim level was effectively attained.

Working process of the designed parabolic solar concentrator shows that once the temperature gets to the maximum boundary, the parabolic dish is triggered to move away from the direct hit of solar irradiances. The relationship between solar angle, solid angle had a positive perfect result and satisfactory to achievement of the specific objectives.

Most industries use thermostat as a way of controlling heat level by shutting down the source; for our case we cannot shutdown the sun. Instead, we have decided to switch the parabolic dish to and away from the sun.

This research was done to determine the heat control mechanism, however in so doing the maximization of solar intensity and harvest was our primary goal, therefore not all necessary measures was taken into consideration for heat maximization during times when there is no sunrise, night times and cloud days. We therefore recommend heat storage mechanism to be part of improving this study, so that enough heat can be stored to be used during night times and days when there are no enough solar radiations.

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