OPTIMIZATION OF SOLAR ENERGY TECHNOLOGIES FOR SUSTAINABLE POWER SUPPLY IN ENUGU STATE.

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ABSTRACT

The poor supply of electricity is accountable for slow pace of development. Over the years, mankind has relied on non renewable sources of energy for electric power generation. In quest for alternative sources of energy that could be renewable, sustainable, environment friendly, pollution free and above all, energy that could meet the demand of the whole world, solar energy system emerged. This study was conducted to determine the strategies for optimization of solar energy for sustainable power supply in Enugu State. The population for the study was 108 which comprised of 37 technicians and 71 technologists from solar firms in Enugu State. Due to manageable size, there was no sampling. Three research questions were raised and answered using mean and standard deviation while hypotheses formulated were tested using t-test at 0.05 level of significance. The study adopted a descriptive survey research design while data were collected using a structured questionnaire developed by the researcher. The instrument was validated by three experts. The reliability of the instrument was established using Cronbach's alpha which gave a high co-efficient index of 0.87. Some of the findings among others included that automatic solar tracker can assist to a great extent in the optimization of solar energy for sustainable power supply in Enugu State; solar module system design can assist in optimization of solar energy for sustainable power to a great extent. It was therefore recommended that modification of solar system component as to integrate shade tolerance software is required by engineers, manufacturers, technicians and technologists so as to expand solar market worldwide; more awareness should be created on solar system components as to enable technicians and technologists to understand the benefits of the application of automatic solar tracker for the optimization of solar energy for sustainable power supply in Enugu State.

KEYWORDS: *Optimization, Solar energy, technologies, Sustainable, Power supply*

INTRODUCTION

It is a known fact that industrialization and availability of social amenities are closely used as a measure of development, thus the classification of some nations as developed, developing and under developed. No nation can be classified as developed without adequate supply of infrastructural facilities which includes electricity. The poor supply of electricity is accountable for slow pace of development especially when the supply is inadequate and epileptic in nature.

In Nigeria and in Enugu State in particular, electricity distribution has been very poor. Previous and successive governments had promised to do something drastic to stabilize the power sector in order to bring about growth in the industry and improvement in standard of living, yet the nation has been plagued with chronic under-development in every area of life. This is evident especially in the area of unreliable and epileptic power supply and this has affected the performance of the industrial sectors of the economy (Leke, 2005). Over the years, the bulk of power generation has been sourced from wind, gas turbine and coal as fuel for thermal power system. Later on, came the construction of hydro-electric power stations at Niger (Kainji dam), Jebba and Shiroro respectively, but all has not accounted for adequate power distribution amongst all the power stations (Jimoh, 2016). The generated capacity of all power supply stations in Nigeria is far below the country's electricity demand, thus, resulting in epileptic supply of electricity in the country.

The supply of electricity in Nigeria is be deviled with consistent crisis as exemplified by such indicators as electricity blackouts, low voltages and persistent self generating electricity (Okafor, 2008). In the same mindset, Ekpo (2009) noted that Nigeria is running a generator economy with adverse effect on cost of production. The country's electricity market is dominated on supply side by the government and private owned sectors yet the sectors have been incapable of providing minimum international standards of electricity services that are reliable, accessible and available for the past decades for her citizens.

Enugu State according to *Williams (2016)*is one of the states in the South East geo-political Zone of Nigeria. It is located at 6o30' North of Equator, and 7o30' East of Latitude. It is plus one hour (+1hr) GMT on the World Time Zone. It shares border with the following states: Abia and Imo to the south; Ebonyi to the east, Benue to the north-east, Kogi to the north-west and Anambra State to the west. Enugu State is made up of 17 local government areas and six education zones. The State enjoys average sunshine of about six hours daily with a population of over one million according to year 2016 estimate. The State's economy which disaggregated into industry, transport, commercial agriculture and household sectors has suffered epileptic power supply. This has brought about a widening trade imbalance, growing competition from developed cities, high cost of living, collapse of big manufacturing companies and sharp increase in the cost of doing business. The State economy demands an alternative source of energy which is reliable, accessible, available and sustainable.

According to International Energy Agency (2007), sustainable energy is an energy that serves the needs of the present without compromising the ability of the future generation to meet their needs. In the process of organizing sources of sustainable power that is environmental friendly and pollution free, solar energy system emerged. Karlsson (2007) pointed out that the earth as a resource system has a limited capacity for supporting a growing population with an intensive exchange of materials and energy with its environment, hence the need for a growing awareness to achieve a more sustainable societal use of materials. The earth receives energy from the sun directly. It is silent, inexhaustible and non-polluting (Eastop and McConkey, 2002).

The idea of using the power from the sun has held solar scientists in their grip for centuries. Also, for most of its evolution, mankind relied for his sources of energy on constantly replenished materials (Bradley 2004). When the use of fire was discovered for the provision of heat and for the processing of food, the additional demand for energy was met by constantly renewed sources. Secondly, when water and wind powers were harnessed to the service of mankind, the new sources were also of a renewable nature. Thus, throughout the early phase of human development, the availability of readily renewable source of energy was a key constant and it has affected the size and distribution of population (Sambo, 2001). Until recently, solar energy system through the discovery of more efficient methods has seen remarkable improvements for its potentials.

Solar energy is the radiant light and heat from the sun that is harnessed using a range of ever-evolving technologies such as solar photo-voltaic and solar thermal energy (International Energy Agency, 2011). Solar is an important source of renewable energy and its technologies are broadly characterized as either passive solar power or active solar depending on how they capture and distribute solar energy or covert it into solar power. Active solar technologies involve the use of photovoltaic system, concentrated solar power and solar water heating to harness the energy (https://en.wikipedia.org/wiki/solar_power). Passive solar techniques includes orienting a building to the sun, selecting materials that is of favoaurble thermal mass or high dispersing properties and designing spaces that naturally circulates air.

Solar thermal is the heating of fluids that produce steam to drive turbines for large scale centralized generation like solar cells. Solar thermal system also called concentrated solar power (SP) uses solar energy to produce electricity but in a different way. Most solar thermal systems use a solar collector with tumor surface to focus sunlight onto a receiver that heats a liquid. The super heated liquid is used to make steam to produce electricity in the same way coal plants do (Federal Ministry of Power and Steel, 2006). Solar electric (Photovoltaic) is the direct conversion of sunlight into electricity through a photocell. Solar photovoltaic system is made up of a balance of system (BOS) which consists of a mounting structure for modules, power conditioning equipment, tracking structure, concentrators system and storage devices.

International Energy Agency (2011), asserted that the development of affordable, inexhaustible and clean solar energy technologies will have huge long-term benefits: it will increase the States security through reliance of indigenous, inexhaustibility and most important-independent resource, enhance sustainability, reduce pollution, lower the cost of mitigating global warming and keep fossil fuel price lower than otherwise. The large magnitude of solar energy available makes it a highly appealing source of electricity. The United Nations Development Prorgamme in its 2000 world energy assessment found out that the annual potential of solar energy was 1,575-49837 exajoules (EJ) which is several times larger than the total world energy consumption which was 559.8EJ in 2012 (World Energy Statistics, 2014). In the same vein, the International Energy Agency projected in 2014 that under its high renewable scenario, by 2050, solar photovoltaic and concentrated power would contribute about II and 16 percent of energy respectively, of the worldwide electricity consumption and solar would be the world's largest source of electricity (International energy Agency, 2014). In the view of the above, Hoff and Cheny (2000) noted that the total amount of energy that the earth receives daily is about 1353w/m^2. Some million tons of the suns matter will continue to be changed into energy every second. Furthermore, Rochell (2010) stressed that solar energy is the most readily and widely available energy source capable of meeting the energy needs. The author noted however, that its technologies has lacked efficiency in production of desired power as a result of lack of awareness and knowledge, practical skills in solar installation, operation, repairs and maintenance of existing solar system by technicians and technologists. Technicians in the context of this study refers to workers in the field of technology with relevant practical skills and techniques with ordinary national diploma certificates from Institutions of higher learning while technologists are technology specialists with higher national diploma and degree certificates in technology from Institutions of higher learning. The later group is expected to have more knowlede about solar energy than the former group. In Enugu State, industrial and domestic users have found solar system inefficient as solar panels that have been on the streets/roads using solar energy are no more working while some of the household equipment using solar energy fail/stop working within few days or weeks thereby discouraging the use of energy from the solar system. Against the backdrop is the need for optimization of solar energy technologies for sustainable power supply Enugu State.

STATEMENT OF THE PROBLEM

In Enugu state, the economy is disaggregated into industry, transport, commercial, agriculture and household sectors. Household in its own seems to be dominating energy consumption. The energy consumption in the household sector include: cooking, lighting and operation of electrical/electronic appliances. Hence, the states economy has been deeply challenged due to the epileptic nature of power supply. The industrial and domestic sectors have resorted to the use of generating sets, which are costly and hazardous to living. In addition, solar energy system that has emerged as sustainable power source, that is also environmentally friendly and pollution free has not been efficient due to lack of skilled human resources in its technological installation, operation, design, repairs and maintenance. All these result amount to low voltage production, limited service life span and the likes. This therefore suggested the need for skill improvement for optimization of solar energy and its technologies for sustainable power supply Enugu State.

PURPOSE OF THE STUDY

The main purpose of this study was to determine the strategies for the optimization of solar energy for sustainable power supply in Enugu State. Specifically the study sought to;

1. Determine how automatic solar tracker can optimize solar energy for sustainable power supply in Enugu State.

2. Determine how solar module system design can optimize solar energy for sustainable power supply in Enugu State.
3. Determine how shade tolerance software can optimize solar energy for sustainable power supply in Enugu State.

RESEARCH QUESTIONS

The following research questions guided the study;

1. How can automatic solar tracker optimize solar energy for sustainable power supply in Enugu State?
2. How can solar module system design optimize solar energy for sustainable power supply in Enugu State?
3. How can shade tolerance software optimize solar energy for sustainable power supply in Enugu state?

HYPOTHESES

The following null hypotheses formulated and tested at .05 level of significance guided the study.

$H0_1$: There is no significant difference in the mean ratings of electrical technologists and technicians on how automatic solar tracker can optimize solar energy for sustainable power supply in Enugu State.

$H0_2$: There is no significant difference in the mean ratings of electrical technologists and technicians on how solar module design can optimize solar energy for sustainable power supply in Enugu State.

H03**:** A significant difference does not exist in the mean ratings of technicians and technologists on how solar tolerance software can optimize solar energy for sustainable power supply in Enugu State.

RESEARCH METHODS

Survey research design was adopted since the purpose of the study was to obtain data by the use of questionnaire. A survey research design is one which involves the assessment of public opinion using questionnaire and sampling methods (Alio, 2008). The study was carried out in solar firms in Enugu State. The choice of the area was as a result of many solar establishments located in the State. The population for the study was 108 which comprised of 37 technicians and 71 technologists from solar firms in the under listed sections of Enugu metropolis; Trans – Ekulu, Abakapa, Ogui road, Achara Layouts, Zik avenue, Uwani, GRA and Obiagu respectively. A preliminary survey was carried out to identify the solar firms. The entire population was used as the population size was manageable. Data was collected using a structured 21-item questionnaire developed by the researcher. The questionnaire item has a four point rating scale with the response options of Very Great Extent (VGE), Great Extent (GE), Less Extent (LE) and Very Less Extent (VLE). The response categories were assigned numerical values of 4, 3, 2 & 1 respectively. The instrument was validated facially by three experts; one expect from a solar firm and two lecturers from the Department of Technology and Vocational Education, Enugu State University of Science and Technology (ESUT) Enugu. The reliability of the instrument was established using Cronbach's alpha which gave a high reliability co-efficient index of 0.87. Cronbach's Alpha was used because the instrument was not dichotomously scored (Uzoagulu, 2011).

Mean and standard deviation were used to answer the research questions. Upper and lower limits of the mean were used as basis for decision, thus items with mean responses within the range of the limit of values of : 1.00 – 1.49; 1.50 – 2.49; 2.50 – 3.49 and 3.50 – 4.00 were remarked VLE, LE, GE and VGE respectively. The null hypotheses were tested using t-test at .05 level of significance. The null hypothesis was rejected when t-cal was greater than t-critical otherwise it was not rejected.

RESULTS

The results are presented in line with the research questions and hypotheses that guided the study.

Research Question 1

How can automatic solar tracker optimize solar energy for sustainable power supply in Enugu State?

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Table 1:

Mean and Standard Deviation of how automatic solar tracker can optimize solar energy for sustainable power supply in Enugu State.

S/N	Solar tracker optimizes solar energy for sustainable power supply by:	**Technicians (37)**			**Techno. (71)**			**Aggregate**		
		$\bar{x}$	SD	D	$\bar{x}$	SD	D	$\bar{x}$	SD	D
1	Tracks the sun throughout the course of the day.	2.96	0.50	GE	3.81	1.04	VGE	3.39	0.77	GE
2	Generates more electricity than stationary counterparts.	2.48	0.53	GE	3.46	0.23	VGE	2.94	0.38	GE
3	Maximizes energy gain during peak time of the day.	2.71	1.03	GE	3.23	0.93	GE	2.97	0.98	GE
4	Ideal for optimizing land usage.	2.64	0.61	GE	2.78	0.64	GE	2.71	0.63	GE
5	Low maintenance due to advanced technology	3.42	0.47	GE	3.06	0.33	VGE	3.49	0.40	GE
6	Enhancing the effectiveness of solar panel.	3.34	0.67	GE	2.94	0.92	GE	3.14	0.80	GE
7	Maximizes efficiency cells while reducing costs.	3.64	0.68	VGE	2.83	0.32	GE	3.24	0.50	GE
	G.**MEAN/SD**	**3.02**	**0.64**	**GE**	**3.22**	**0.63**	**GE**	**3.13**	**0.64**	**GE**

With reference to the Table 1, the mean responses of technicians and technologists reveal that items 1 to 7 were to a great extent with mean aggregate scores ranging from 2.71 to 3.49. The Table shows that automatic solar tracker can assist to a great extent in the optimization of solar energy for sustainable power supply in Enugu state. The grand mean also attested to that. The standard deviation ranged from 0.38 to 0.98 indicating homogeneity of opinions.

Research Question 2

How can solar module system design optimize solar energy for sustainable power supply in Enugu State?

Table 2:

Mean and Standard Deviation of howsolar module system design can optimize solar energy for sustainable power supply in Enugu State.

S/N	Solar module system design can optimize solar energy for sustainable power by:	Technicians (37)			Technolo. (71)			Aggregate		
		$\bar{x}$	SD	D	$\bar{x}$	SD	D	$\bar{x}$	SD	D
8	Improving system performance without increasing cost.	3.64	0.68	VGE	2.83	0.32	GE	3.24	0.50	GE
9	Placing modules to south for efficient productivity.	2.34	0.49	LE	2.20	1.35	LE	2.27	0.92	LE
10	Series connected design for increased voltage.	2.51	1.43	GE	2.41	0.78	LE	2.46	1.11	LE
11	Parallel connected design for increased current.	2.63	1.08	GE	2.33	1.06	LE	2.48	1.70	LE
12	Maximizes sunlight through proper spacing of modules.	3.41	0.66	GE	3.56	1.65	VGE	3.49	0.94	GE
13	Minimize shading.	3.11	0.82	GE	3.67	1.05	VGE	3.39	0.94	GE
	G.**MEAN/SD**	**2.94**	**0.86**	**GE**	**2.83**	**1.03**	**GE**	**2.88**	**1.06**	**GE**

Table 2 shows that items 8, 12 and 13 with mean scores of 3.24, 3.49 and 3.39 can assist to a great extent while items 9, 10 and 11 with mean scores of 2.27, 2.46 and 2.48 can assist to a low extent in the optimization of solar energy for sustainable power supply in Enugu. However, the grand mean of 2.88 shows that solar module system design can assist as a strategy in optimizing solar energy to a great extent. The grand standard deviation of 1.06 also shows that the opinions of the respondents are close.

Research Question 3

How can shade tolerance software optimize solar energy for sustainable power supply in Enugu state?

Table 3:

Mean and Standard Deviation of how shade tolerance software can optimize solar energy for sustainable power supply in Enugu State.

S/N	Shade tolerance software can optimize solar energy for sustainable power by:	Technicians (37)			Technolo. (71)			Aggregate		
		$\bar{x}$	SD	D	$\bar{x}$	SD		$\bar{x}$	SD	D
14	Analysis losses from shade.	2.36	0.82	GE	3.67	1.05	VGE	3.39	0.94	GE
15	Accuses system cost-benefit of adding modules.	2.70	1.03	GE	2.33	1.06	GE	2.48	1.70	GE
16	Minimize shading losses.	1.96	1.34	LE	3.37	0.48	GE	2.67	0.91	GE
17	Programmes to enable detailed shade calculation.	3.27	0.83	GE	2.43	0.45	GE	2.85	0.64	GE
18	Eliminate modules that are shade.	2.14	0.86	LE	2.00	0.50	LE	2.07	0.68	LE
19	Programmes to enable detailed mismatched calculations.	3.19	0.68	GE	3.44	0.48	GE	3.32	0.58	GE
20	Add modules.	2.78	0.51	GE	1.93	0.65	LE	2.36	0.58	GE
21	Remove modules.	2.86	0.63	GE	3.01	1.11	GE	2.94	0.87	GE
	G.**MEAN/SD**	**2.68**	**0.38**	**GE**	**2.77**	**0.72**	**GE**	**2.76**	**0.86**	**GE**

Table 3 showed that items 14, 15, 16, 17, 19, 20 and 21 with mean scores of 3.39, 2.48, 2.67, 2.85, 3.32, 2.36 and 2.94 can assist to a great extent while item 18 with mean score of 2.07 can assist to a less extent in the optimization of solar energy for sustainable power supply in Enugu. However, the grand mean of 2.76 suggests that solar module system design can assist as a strategy in optimizing solar energy to a great extent. The pull standard deviation of 0.86 shows that the disparity in the opinion of respondents is slim.

Hypotheses

$H0_1$: There is no significant difference in the mean ratings of solar technicians and technologists on how automatic solar tracker can optimize solar energy for sustainable power supply in Enugu State.

Table 4:

t-test analysis between solar technicians and technologists on how automatic solar tracker can optimize solar energy for sustainable power supply in Enugu State

Respondents	No	Aggregate		Df	P	t-criti	t-cal	Decision
		$\bar{x}$	SD					
Technicians	37	3.02	0.64	106	0.05	1.671	1.63	Not Significant
Technologists	71	3.22	0.63					

The t-test results show that t-cal(1.63) is less than t-critical (1.67) at 106 degree of freedom. Therefore since the t-cal (1.63) is less than t-critical (1.671), the null hypothesis is not rejected. This implies that there is no significant difference in the mean ratings of solar technicians and technologists on extent to which automatic solar tracker can assist in optimization of solar energy for sustainable power supply in Enugu State.

$H0_2$: There is no significant difference in the mean ratings of solar technicians and technologists on how solar module system design can optimize solar energy for sustainable power supply in Enugu State

Table 5:

t-test analysis between solar technicians and technologists on extent to which solar module system design can assist in the optimization of solar energy for sustainable power supply in Enugu State

Respondents	No	Aggregate		Df	P	t-criti	t-cal	Decision
		$\bar{x}$	SD					
Technicians	37	2.94	0.86	106	0.05	1.671	0.61	Not Significant
Technologists	71	2.83	1.03					

The t-test result above show that t-cal (0.61) is less than t-critical (1.671) at 106 degree of freedom, therefore since the t-cal is less than t-critical, the null hypothesis is not rejected. This implies that there is no significant difference between the mean ratings of technicians and technologists on extent to which solar module system design can assist in the optimization of solar energy for sustainable power supply in Enugu State.

H03; There is no significant difference in the mean ratings of solar technicians and technologists on how shade tolerance software can optimize solar energy for sustainable power supply in Enugu State

Table 6:

t-test analysis between solar technicians and technologists how shade tolerance software can optimize solar energy for sustainable power supply in Enugu State

Respondent	No	Aggregate		Df	P	t-cal	t-crit	Decision
		$\bar{x}$	SD					
Technicians	37	2.66	0.38	106	0.05	0.12	1.671	Not
Technologists	71	2.77	0.86					Significant

The t-test result above shows that t-cal (0.12) is less than t-critical (1.671) at 106 degree of freedom. Therefore since the T-cal is less than T-critical, the null hypothesis is not rejected. This implies that there is no significant difference in the mean ratings of technicians and technologists on extent to which state tolerance software assist in the optimization of solar energy for sustainable power supply in Enugu State.

DISCUSSION OF FINDINGS

The study revealed that automatic solar tracker can optimize solar energy for sustainable power supply by tracking the sun throughout the course of the day, generate more electricity than stationary counterparts, maximizes energy gain during peak of the day. This is in agreement with the findings of Alekand Astislek (2016) which revealed that solar tracking controlling system has multiple functions and uses two meters as the drive source which has the ability of conducting an approximate hemispheroidal 3-D relation on the solar energy which minimizes system's power consumption during operation and increases efficiency and total amount of electricity generated. Their findings agreed with that of

Sungar (2009) that Multi-Axes sun tracking system with control can help in optimization of solar energy for sustainable power supply.

The study further revealed that solar module system design can assist in optimization of solar energy for sustainable power to a great extent. This is in agreement with the findings of Ruth, Georgiev and Baudinov (2009) which pointed out that the design of photo-Voltaic panels can assist in the optimization of solar energy. It is also paramount to state that the study also revealed that technicians and technologist agree to a great extent that state tolerance software can assist in the optimization of solar. This is in consonance with the findings of Paul and Paul (2016) which states that a measured shade tolerance can optimize a PV system profitability and efficiency for power supply.

The hypotheses tested using t-test at .05 level of significance showed that there is no significant difference in the mean ratings of electrical technicians and technologists on extent to which solar optimization strategies (automatic solar tracker, solar module system design and shade tolerance software) can assist in the optimization of solar energy for sustainable power supply in Enugu State.

CONCLUSION

Based on the findings of this study, technicians and technologists agreed to a great extent that optimization of solar energy could be achieved using automatic solar tracker for sustainable power supply by tracking the sun throughout the course of the day and enhancing the effectiveness of solar panel. Also, both technicians and technologists agreed to a great extent that solar module system design can assist in the optimization of solar energy by maximizing sunlight through proper spacing of modules and improving system performance without increasing cost. Furthermore, both technicians and technologists agreed to a great extent that solar shade tolerance software can assist in the optimization of solar energy by analyzing losses from shading, eliminate modules that are shaded and add modules. It is believed that when these strategies are imbibed and put into use, sustainable power supply will be achieved and enjoyed in Enugu State.

RECOMMENDATION

The following recommendations were made in view of the findings of the study:

1) More awareness should be created on solar system components as to enable technicians and technologists to effectively understand the principles and application of solar tracker for effective optimization of solar energy.
2) Training on solar modules system design is highly required for its effective utilization as an optimization technique.
3) Solar shade tolerance software embedded systems should be produced at large replace obsolete systems and as well, expand solar market worldwide.
4) Government should ensure low cost of importation duties so as to encourage new designs and standard solar system components.

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