THE MAINTENANCE AND ENERGY SAVING STRATEGIES FOR HVAC INSTALLATIONS IN HOTELS IN OWERRI, IMO STATE

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Abstract
Decreasing the energy consumption or reducing the energy wastages of Heating, Ventilation and Air Conditioning (HVAC) Systems is becoming increasingly important due to rising cost of fossil fuels and environmental concerns. Therefore, finding novel ways to reduce energy consumption in buildings without compromising comfort and indoor air quality is an ongoing research challenge. Thus, this research was conceived to study maintenance of the major components of the HVAC and its energy consumption implication as well as possible energy saving strategy that can be adopted. It was pursued, by means of literature review and field survey entailing the use of a well-structured questionnaire. A total of three hundred and forty-two (342) questionnaires were returned adequately and the responses were analyzed using the computer SPSS software version 25. The result revealed among others that, the most maintained component of the HVAC system are the chillers;the maintenance of the HVAC systems was inadequate and the mmaintenance of the HVAC systems was informed by the following facts in the order of severity; availability of fund, faulty operation of the system and in few occasion it is a normal maintenance routine.There is key strategy for saving energy using HVAC system. The maintenance of HVAC installations significantly affects its energy consumptions in the area. Thus, the study recommends among others: Uniformity in the maintenance of all the HVAC components, and a prompt response to the need for the maintenance of HVAC installations.

Key words: Maintenance, Energy Saving Strategy, HVAC Installations

Introduction

In many countries, buildings consume more energy than transport and industry. The International Energy Agency (IEA) statistics estimate that globally, the building sector is responsible for more electricity consumption (42%) than any other sector. The building sector encompasses a diverse set of end use activities, which have, different energy use implications. Space heating, space cooling and lighting, which together account for a majority of building energy use in industrialized countries, depend not only on the energy efficiency of temperature control and lighting systems, but also on the efficiency of the buildings in which they operate. Other factors include; the building designs and materials, which have a significant effect on the energy consumed as well as the selection of the set of end use facilities (IEA, 2004).

The growing trend in building Energy consumption will continue during the coming years due to the expansion of built area and associated energy needs, as long as resources and environmental exhaustion or economic recession allows it. Therefore, private initiative together with government intervention through the promotion of energy efficiency, new technologies for energy production, limiting energy consumption and raising social awareness on the use of energy will be essential to make possible a sustainable future (Luis *et al*, 2008)

In non-domestic buildings, the type of use and activities make a huge impact on the quality and quantity of energy services needed. Non-residential building include the public buildings as well as the industrial buildings which account for a large amount of the energy consumption in the building sector (Energy Information Administration, International Energy, 2006)

However, in Nigeria, most of the efforts are channeled towards developing sustainable energy generation processes with little or no attention given to the energy consumption end use facilities uses and the amount of energy these end use facilities use. Therefore, identifying the major end uses of the energy generated and proper management thereof, ought to be given similar attention for potential energy saving in the building sector for sustainability. Thus, this study is timely as Nigeria is currently experiencing serious energy crisis and massive energy wastage which is accompanied with the environmental depletion.

Decreasing the energy consumption or reducing the energy wastages of Heating Ventilation and Air Conditioning (HVAC) systems is becoming increasingly important due to rising cost of fossil fuels and environmental concerns. Therefore, finding novel ways to reduce energy consumption in buildings without compromising comfort and indoor air quality is an ongoing research challenge (Vakiloroaya, 2014). The reality of the energy management of HVAC installation lies on the predictive approach adopted in order to envisage the energy consumption and consequently plan the energy consumption.

Thus this paper seeks to ascertain the level of maintenance of HVAC system components installations and its energy consumption implications and determine the key strategies for saving energy while using the HVAC installation system in Owerri Nigeria.

Methodology

The study was pursued through the use of a well-structured questionnaire. Details of the sample size, data collection instrument, design and administration of the questionnaire and data analysis instrument are as presented in this section.

Sample Size

The population studied are public buildings with particular interest in the Hotels in Owerri Municipal. In the context of this study the public buildings allowed relatively unrestricted access and these could include educational and research facilities, car parks, entertainment halls and offices. However due to lack of access and the need to maintain uniformity of data the study opted for only Hotel buildings in Owerri municipal

Cochran's sample size calculation procedure was employed to determine the appropriate sample size in this study. To do this, Cochran's return sample size formula is first determined using the formula presented in equation 1 (Cochran, 1977)

$$\mathbf{N_0 = (z^2pq)/d^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.1)$$

Where;

n = the desired sample size

z = the ordinate on the Normal curve corresponding to or the standard normal deviate, usually any of the following determined based on the 'margin error formula'

i) A 90% level of confidence has $\alpha = 0.10$ and critical value of $z\alpha/2 = 1.64$.

ii) A 95% level of confidence has $\alpha = 0.05$ and critical value of $z\alpha/2 = 1.96$.

iii) A 99% level of confidence has $\alpha = 0.01$ and critical value of $z\alpha/2 = 2.58$.

iv) A 99.5% level of confidence has $\alpha = 0.005$ and critical value of $z\alpha/2 = 2.81$.

P= the proportion in the target population estimated to have particular characteristics (normal between the range of 0.1 to 0.5
q = 1.0-p
d = degree of accuracy corresponding to the confidence level and Z selected.

For the purpose of this study, a confidence level of 95% was adopted owing to the fact that the questionnaire was geared towards evaluating perception on monitoring. Consequently, the sample size is determined as thus,

z = 1.96, d = 0.05 where p = 0.5, q =0.5
N_o= (1.962X0.5X0.5)/ (0.05)2= 384
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Therefore a total of three hundred and eighty-four will be administered to the various respondent's staff and occupants of the Hotels inclusive). Thus, after calculating using Cochran's formula for sample size of 384 respondents (see Equation 3.1), the number of hotels from which the various respondents will be drawn will be deduced from the formula for calculating sample sizes given a known population.

Data Collection Methods and Instruments

As earlier stated that the data set needed for this research is both quantitative and qualitative (i.e. Mixed design research). Applying the mixed research design approach in collating the data set needed to address the research objectives. A questionnaire was adopted.

Design and Administration of Questionnaires

The questionnaire were structured to be consistent with the major aspect of the research such as the research questions and the objectives of the research. The questionnaire was administered to occupants and/staff of the hotels. The questionnaire were used to investigate issues relating to the management, operations, control, maintenance and installation of the HVAC systems in the Hotels and was however prepared in a five point Likert scale.

Method and Instrument of Data Analysis

The data collected for this study was subjected to various statistical analyses using the computer based software "Statistical Package of Social Sciences" (SPSS). The results of the analysis were presented in the form of tables for the purpose of easy comparism and clear expression of the findings. Also, Data obtained through questionnaires were analyzed using mean score, standard deviation, Relative Importance Index and t-test to test the research hypotheses. All analysis was done using Statistical Package for Social Science (SPSS) version 19. Further, the analyses were presented in tables and chart. The Mean Score were computed using this formula:

Mean-score = $\mathbf{(X_1W_1+X_2W_2+X_3W_3+ \ldots\ldots\ldots\ldots\ldots X_nW_n)/N}$ ....(3.3)
Where
W = Weight of answer choice
X = Response count for answer choice
N = Total Numbers of the Respondents

From the computation, most significant constraint factor in a subset was one with the highest Mean-Score value. The factor having an average or higher value is considered significant as shown in Equation 1, while the insignificant factors are identified using Equation 2.

Significant constraint factor: $MR > 2.5$ ………………………. (1)
Non-significant constraint factor: $MR < 2.5$ ……………………….. (2)
Where:

$1 < M < 5$ on 5-point Likert rating scale

Based on the mean score (M) values of the constraints in a given set, the variable were ranked or rated. The standard deviation was computed using this formula:

$$\sqrt{EFi(xi - X)/EFi} \quad \text{…………………………………….. (3.4)}$$

Where:
X = Mean
Efi= Means the frequency of the ith item

Relative importance indices (RII) were also used to rank areas of emphasis during project monitoring. The Relative Importance Index (RII) was calculated for each document according to their frequency of use as suggested for use by Memon et al, (2006) and Othman et al, (2005)

RII ranges between zeros to one. The five-point Likert scale ranking was transformed to relative Importance Indices (RII) for each of the construction contract documents. The weighted average for each item was determined and ranks were assigned to each item, representing the perception of the respondents. Relative Importance Index (RII)

$$= \frac{\sum fx}{\sum f} \times \frac{1}{k} \quad \text{... (3.5)}$$

Where,
∑fx = is the total weight given to each attributes by the respondents.
∑f = is the total number or respondents in the sample.
K = is the highest weight on the likert scale. Results are classified into three categories as follows (Othman et al, 2005)

when;

RII<0.60 -it indicates low frequency in use
0.60≤RII<0.80 -it indicates high frequency in use.

RII≥0.80 –it indicates very high frequency in use

Finally, the data analysis were presented table's and chart's form. However, the analyses were aided using the SPSS (i.e. Statistical Package for the Social Sciences) software.

Result and Discussion

HVAC Maintenance

Table 1: HVAC Maintenance

S/N	Variable	Option	Frequency (No)	Percentage (%)
1	Is there planned maintenance for HVAC systems in the building	a) Yes	98	28.7
		b) No	234	68.4
		c) Don't Know	10	2.9
		Total	**342**	**100**
2	schedule for the planned maintenance	a) 0-6mnths	22	6.4
		b) 7-12 months	94	27.5
		c) 13-18 months	45	13.2
		d) Over 18 months	156	45.6
		e) Don't Know	25	7.3
		Total	**342**	**100**
3	Who is in charge of HVAC system service maintenance	a) Building operator	138	40.4
		b) Maintenance contractor	204	59.6
		c) Nobody	-	-
		Total	**342**	**100**
5	the elements covered by the maintenance or services contract	a) Services or maintenance duration	34	9.9
		b) Filter Replacement or clean up	45	13.2
		c) Duct clean up	56	16.4
		d) Replacement of faulty units/parts	54	15.8
		e) Refrigerant recharge/change	35	10.2
		f) Purging of system	31	9.1
		g) Review of HVAC system performance and operational/ energy efficiency	87	25.4
		Total	**342**	**100**

Source: Field Survey, (2018)

The opinion of the respondents' on the maintenance of the HVAC systems in the hotels and the result is as presented in Table 1. From the Table it can be seen that there is no planned maintenance of the HVAC systems as attested by 68.4%. In line with the maintenance interval, 45.6% of the respondents attested that the HVAC are maintained in interval of over 18thmnths; 27.5% claim it's within 7-12months while 13.2 % claim it is 13-18 months.

The result also shows that most of the HVAC system maintenance are done mainly by maintenance contractors (59.6%) while only 40.4% of the respondents claim it is done by building operators in the Hotels. The researcher also sought to know the elements covered by the maintenance or service contract. From the result it can been seen that 25.4% of claim its 'Review of HVAC system performance and operational/ energy efficiency'; 16.4% 'Duct clean up'; 15.8% 'Replacement of faulty units/parts'. Details of other elements covered by the maintenance service contract are as shown in the table.

Ranking of Maintenance of the HVAC Components

Table 2:Ranking of Maintenance of the HVAC Components

S/N	Maintenance of the HVAC Components	WEIGHTNG/RESPONSE FREQUENCY										
		1	2	3	4	5	(∑f)	∑fx	MEAN	Std	RII	RANK
A	**Chillers**											
1	Check refrigerant level, leak test with electronic Leak detector. If abnormal, trace and rectify as necessary, Inform department in writing on the rectification	50	61	14	173	44	342	1126	3.29	1.33	0.66	4TH
2	Inspect level and condition of oil. If abnormal, trace fault and rectify as necessary. Inform department in writing on the rectification	-	63	51	228	-	342	963	2.82	0.79	0.56	5TH
3	Check the liquid line sight glasses for proper flow	-	106	-	140	96	342	828	2.42	1.19	0.48	8TH
4	Check all operating pressure and temperature	142	08	73	119	-	342	853	2.49	1.34	0.50	7TH
5	Inspect and adjust, if required, all operating safety controls	-	81	14	138	109	342	1301	3.80	1.13	0.76	1ST
6	Check capacity control, adjust if necessary.	50	187	105	-	-	342	739	2.16	0.66	0.43	9TH
7	Lubricate vane/ linkage/	-	04	158	110	70	342	1272	3.72	0.80	0.74	2ND

	bearings.											
8	Visually inspect machine and associated components, and listen for unusual sound or noise for evidence of unusual conditions.	-	46	94	170	32	342	1214	3.55	0.84	0.71	3RD
9	Check lock bolts and chiller spring mount.	-	238	22	49	33	342	903	2.64	1.05	0.53	6TH
10	Review daily operating log maintained by department‘s operating personnel Review daily operating log maintained by department‘s operating personnel	77	265	-	-	-	342	607	1.77	0.42	0.35	10TH
Cluster statistics		**32**	**106**	**53**	**113**	**38**			**3.06**	**1.21**		
B	**WATER PUMPS**											
1	Inspect all water pumps	88	98	35	46	75	342	948	2.77	1.51	0.55	3RD
2	Check all seals, glands and pipelines for leaks and rectify as necessary.	113	75	67	37	50	342	862	2.52	1.42	0.50	5TH
3	Re-pack and adjust pump glands as necessary	145	43	69	85	-	342	778	2.27	1.25	0.45	6TH
4	Check all pump bearings and lubricate with oil or grease as necessary.	67	98	11	116	50	342	1010	2.95	1.41	0.59	2ND
5	Check the alignment and condition of all rubber couplings	92	78	23	135	14	342	927	2.71	1.34	0.54	4TH

	between pumps and drive motors and rectify as necessary.											
6	Check all bolts and nuts for tightness and tighten as necessary.	14	98	16	167	47	342	1161	3.39	1.16	0.68	1ST
Cluster Statistics		**86**	**82**	**37**	**98**	**39**			**2.77**	**1.39**		
C	**AIR HANDLING UNITS AND FAN COIL UNITS**											
1	Inspect all air handling and fan coil units	75	33	54	79	101	342	1124	3.29	1.52	0.66	1ST
2	Check all air filters and clean or change filters as necessary.	54	114	23	134	17	342	972	2.84	1.24	0.57	3RD
3	Check all water coils, seals and pipelines for leaks and rectify as necessary	88	89	46	98	21	342	901	2.63	1.30	0.53	5TH
4	Check and re-calibrate modulating valves and controls. Adjust and rectify as necessary to ensure compliance to the original specifications	91	73	34	124	20	342	935	2.73	1.35	0.55	4TH
5	Purge air from all water coils.	102	113	12	67	48	342	872	2.55	1.44	0.51	7TH
6	Check all fan bearings and lubricate with grease as necessary.	91	121	8	72	50	342	895	2.62	1.43	0.52	6TH
7	Check the tension of all belt drives and adjust as necessary.	156	70	15	34	67	342	812	2.37	1.59	0.47	9TH
8	Check and clean all the condensate	78	67	55	97	45	342	990	2.89	1.38	0.58	2ND

	pans, trays and drains.											
9	Check, clean and service smoke detectors. Carry out a system test to ensure that the smoke detector will trip the AHU‘s.	135	64	43	78	22	342	814	2.38	1.37	0.48	8TH
Cluster Statistics		**97**	**83**	**32**	**87**	**43**			**2.70**	**1.43**		
D	**AIR COOLED PACKAGED UNITS AND PRECISION COMPUTER AIR-CONDITION EQUIPMENT**											
1	Check condenser fan motor load ampere	131	56	43	89	23	342	843	2.46	1.39	0.49	6TH
2	Check fan and motor mounting brackets	123	76	56	87	-	342	791	2.31	1.20	0.46	8TH
3	Check shafts and bearings. Lubricate with grease as necessary.	145	45	54	67	31	342	820	2.40	1.42	0.48	7TH
4	Check the tension of all belt drives and adjust as necessary.	112	34	66	45	85	342	983	2.87	1.59	0.57	2ND
5	Check for refrigerant leaks with electronic leak detector.	109	76	35	77	45	342	899	2.63	1.46	0.53	4TH
6	Check electrical terminals and contactors operation and connection for tightness.	45	66	34	165	32	342	1099	3.21	1.24	0.64	1ST
7	Check compressor motor current	109	49	41	118	25	342	927	2.71	1.41	0.54	3RD
8	Check refrigerant line driers and moisture	90	88	71	77	16	342	867	2.54	1.23	0.50	5TH

	indicators											
Cluster Statistics		**108**	**61**	**50**	**91**	**32**			**2.64**	**1.40**		
E	**AIR DISTRIBUTION SYSTEM**											
1	Check operation of all modulating and fixed dampers controlling air flow through unit. Lubricate all damper bearings and linkages as necessary.	54	45	78	98	67	342	1105	3.23	1.34	0.65	1ST
2	Check noise level of discharged air from Diffusers	77	56	34	87	88	342	1079	3.15	1.53	0.63	2ND
Cluster Statistics		**66**	**51**	**56**	**93**	**76**			**3.18**	**1.43**		
F	**VENTILATION**											
1	Check and adjust as necessary that the air flow of all fans is in compliance with the original specifications.	81	67	56	94	44	342	979	2.86	1.37	0.57	4TH
2	Check the tension of all belt drives and adjust as necessary	76	45	76	88	57	342	1031	3.01	1.40	0.60	3RD
3	Check and lubricate all fan bearings	91	67	56	101	27	342	932	2.73	1.34	0.55	5TH
4	Tighten motor terminals.	71	34	54	89	94	342	1127	3.30	1.49	0.66	1ST
5	Check starter contacts	34	109	52	78	69	342	1065	3.11	1.32	0.62	2ND
Cluster Statistics		**71**	**64**	**59**	**90**	**58**			**3.00**	**1.40**		
G	**SWITCH BOARD**											
1	Clean and adjust all switch gear,	56	45	112	97	32	342	1030	3.01	1.20	0.60	1ST

	contactors, relays and associated electrical equipment at intervals not exceeding six months											
2	Check and prove operation of thermal over load and protection devices.	154	35	56	86	11	342	791	2.31	1.35	0.46	4TH
3	Check and ensure tightness of all equipment fastenings and cable terminations within switch boards	132	56	31	77	46	342	875	2.56	1.51	0.51	3RD
4	Vacuum clean all switch board cubicles	112	53	67	78	32	342	891	2.61	1.39	0.52	2ND
Cluster Statistics		**114**	**47**	**66**	**85**	**30**			**2.62**	**1.39**		
H	**PIPING SYSTEM**											
1	Check all piping system for leaks and repair these where they have occurred	67	72	45	97	61	342	1039	3.04	1.41	0.61	1ST
2	Check for damage & deterioration of insulation or sheathings. Rectify as necessary	58	76	79	92	37	342	1000	2.92	1.27	0.58	2ND
Cluster Statistics		63	74	62	94	49			**2.98**	**1.34**		

Source: Field Survey, (2018)

Where: ND= Never Done; RD= Rarely Done; NI= No Idea; OD= Often Done; AD= Always Done

The Likert scale result in table 2 presents the ranking of the maintenance of the HVAC component. From the result in of the Table, the HVAC component. is divided into various Components namely: Chillers (with cluster mean value of 3.06 and standard deviation of 1.21), Water Pumps (with cluster mean value of 2.77 and standard deviation of 1.39), Air Handling Units and Fan Coil units, Air cooled package units and precision

computer air-condition (with cluster mean value of 2.64 and standard deviation of 1.40), Air Distribution System (with cluster mean value of 3.18 and standard deviation of 1.43), ventilation, Switch Board (with cluster mean value of 3.00 and standard deviation of 1.40), and Piping system (with cluster mean value of 2.98 and standard deviation of 1.34). From the cluster mean value it indicates that of all the various component of the HVAC system, the Air Distribution System is the component that is often maintained compared with the other component based on the mean.
However within the various section of the HVAC system the following are the result of the ranking of the various component that make up the sections:

a) In the chillers, the respondent ranked "Inspect and adjust, if required, all operating safety controls" (RII=0.76) as the most carried out maintenance practice for the chillers. This was closely followed by "Lubricate vane/ linkage/ bearings: (RII=0.74), "Visually inspect machine and associated components, and listen for unusual sound or noise for evidence of unusual conditions" (RII= 0.71), and "Check refrigerant level, leak test with electronic Leak detector. If abnormal, trace and rectify as necessary, Inform department in writing on therectification (RII=0.66) which ranked second, third and fourth respectively. Details of the ranking of other factors that relates to the chillers as a component of the HVAC system is as presented in the Table.
b) In the Water Pumps, the respondents ranked "Checking all bolts and nuts for tightness and tighten as necessary" (RII=0.68) was ranked the first as the most maintained aspect of the water pump. This was also followed closely followed by: "Checking all pump bearings and lubricate with oil or grease as necessary" (RII=0.59) and "Inspection of all water pumps" (RII=0.55), which ranked second and third respectively. Details of the ranking f other maintenance aspect of the Water Pump are as presented in the Table.
c) In the Air Handling Units and Fan coils, Units; "Inspection of all air handling and fan coil unit" (RII=0.66) was ranked first. "Checking and cleaning all the condensate pans, trays and drains" (RII=0.58) was ranked Second while the "Checking all air filters and clean or change filters as necessary" (RII=0.57) was ranked third. Details of the ranking of other maintenance process of the Air handling Units and Fan coil units are as presented in the Table.
d) In the Air Cooled Packaged Units and Precision Computer Air Conditioning Equipment, the respondents ranked "Checking electrical terminals and contactors operation and connection for tightness"(RII=0.64) as the first while the lease ranked maintenance procedure is "Checking fan and motor mounting brackets" (RII=0.46). Details and ranking of other maintenance procedures are as shown in the Table.
e) In the Air Distribution System, "Checking operation of all modulating and fixed dampers controlling air flow through unit. Lubricate all damper bearings and linkages as necessary" (RII=0.65) was ranked the first
f) In the Ventilation Component of the HVAC system maintenance, "Tighten motor terminals" (RII=0.66) was ranked first. While "Check starter contacts" (RII=0.62) and "Checking the tension of all belt drives and adjust as necessary (RII=0.60) were ranked the second and third commonly done maintenance practice on the ventilation component of the HVAC systems in the Hotel respectively. Details of the ranking of other procedure are presented in the Table.
g) In the Switch Board, the respondents ranked "Cleaning and adjusting all switch gear, contactors, relays and associated electrical equipment at intervals not exceeding six months" (RII=0.60) as the commonly practice maintenance procedure of the Switch board in the Hotels. The details of the ranking of other procedure of the Switch board is presented in the Table

h) Finally in the Piping system as a component of the HVAC system, "Checking all piping system for leaks and repair these where they have occurred" (RII=0.61) was ranked first while "Checking for damage & deterioration of insulation or sheathings. Rectify as necessary" (RII= 0.58) was ranked Second.

Effect of the maintenance of HVAC system on its Energy Consumption

Table 3: Effect of the maintenance of HVAC system on its energy consumption

VARIABLES	Yes/High Extent (%)	Not Sure or Inconsequential (%)	No/Low Extent (%)	Mean	Std. Dev.
Maintenance of HVAC system affects Energy consumption	284 (83.0%)	0 (0.0%)	58 (17.0%)	2.66	0.752
Adequate maintenance of the HVAC system will help to reduce energy wastage and optimal use of energy	292 (85.4%)	33 (9.6%)	17 (5.0%)	2.80	0.508
Extent of agreement that energy is consistently wasted due to nature of the maintenance of the HVAC systems	314 (91.8%)	17 (5.0%)	11 (3.2%)	2.89	0.407
Urgent need of improving the maintenance of the HVAC for a sustainable energy consumption	262 (76.6%)	0(0.0%)	80 (23.4%)	2.53	0.848
Cluster Mean	**84.2%**	**3.7%**	**12.1%**	**2.72**	**0.629**

Source: Field Survey, (2018)

Table 3 presents the Effect of the maintenance of the HVAC installations on the energy consumption. From the Table it can be deduce that a larger percentage of the respondents opined that the maintenance highly affect the energy consumption of the system (83.0%). Similarly, 85.4% of the respondents identified that adequate maintenance of the system can help reduce the energy wastage and optimize energy consumptions of the HVAC systems. Also, 76.6% of the respondents attested to the fact that there is an urgent need to improve the maintenance of the HVAC installations so as to improve the energy consumption.

Energy Saving and HVAC Control Functionality

Table 4Energy Saving and HVAC Control Functionality

S/N	Variable	Option	Frequency (No)	Percentage (%)
3	The focuses of the energy saving program with regards to HVAC system?	a) Demand reduction by minimum operation of system	67	19.6
		b) Introduction of an	45	13.2

		energy management system		
		c) Demand scheduling	47	13.7
		d) HVAC system retrofit	50	14.6
		e) Energy efficient maintenance program	89	26.0
		f) Duct cleaning	44	12.9
		Total	**342**	**100**
4	the control type/strategies used for HVAC system operation in the building	a) On/off toolbox	198	58.9
		b) Automatic thermostat based control	64	18.7
		c) Variable Fan speed adjuster	10	2.9
		d) Air intake control	13	3.8
		e) Carbon dioxide sensors	-	-
		f) Variable motor speed adjuster	12	3.5
		g) Timers	45	12.2
		Total	**342**	**100**
5	what are the observable faults in the HVAC control	a) Control setting are very low	56	16.4
		b) Control knobs are broken	18	5.3
		c) Control settings are higher than desired	30	8.8
		d) Control sensor faulty	125	36.5
		e) Adjusters are faulty	113	33.0
		Total	**342**	**100**

Source: Field Survey, (2018)

The Energy Saving and HVAC Control functionality of the Hotels were assessed and the result is presented in Table 4 from the table, it is seen that the focus of most of the energy saving programme in the Hotels is mainly ‘energy efficiency’ (26.0%). Other major focuses are; ‘Energy demand reduction by minimum operation of system’ (19.6%), ‘HVAC system retrofit’ (14.6%), ‘Demand scheduling’ (13.7%) and ‘Introduction of an energy management system’ (13.2%) arranged in their order of severity.

It can also be seen that the most common HVAC operation control type and strategy used in most of the Hotels studied is ‘On/off toolbox’ (58.9%). Also, ‘Automatic thermostat based control’ (18.7%) identified as the second most common HVAC operation control strategy adopted in the Hotels. Details of other control strategy used are also presented in the table.

The Table also presents the observable faults in the HVAC Control system in the hotels. It is seen that the most common fault often observed in the HVAC control is ‘Control Sensor Faults’ (36.5%). This is closely followed by; ‘Adjusters are faulty’ (33.0%); ‘Control setting are very low’ (16.4%) and ‘Control settings higher than desired’ (8.8%) arranged in the order of severity

Energy Saving Strategies for HVAC Systems

Table 5: Ranking Of the Strategies to Be Used To Save Energy When Using HVAC System

S/N	Control Measures	RESPONSE FREQUENCY									
		SD	D	U	A	SA	(∑f)	∑fx	MEAN	RII	RANK
1	On/off toolbox	-	11	14	271	46	342	1,378	4.02	0.81	3rd
2	Timers	-	-	51	248	43	342	1,360	3.98	0.80	4th
3	Automatic thermostat based control	-	-	-	246	96	342	1,464	4.28	0.86	1st
4	Variable Fan speed adjuster	-	08	143	119	72	342	1,281	3.74	0.75	5th
5	Air intake control	30	50	111	138	13	342	1080	3.16	0.63	7th
6	Carbon dioxide sensors	-	50	105	187	-	342	1163	3.40	0.68	6th
7	Variable motor speed adjuster	-	6	-	265	71	342	1427	4.17	0.83	2nd

Source: Field Survey, (2018)

Where: SD= Strongly Disagree; D= Disagree; U= Undeceive; A= Agreed; SA= Strongly Agreed

Weights: SD = 1; D = 2; U = 3; A = 4; SA = 5

Table 5, presents the respondents ranking of the energy saving strategies for HVAC systems. From the Table it can be seen that 'Automatic thermostat' (RII=0.86) was ranked first as the most promising HVAC energy saving strategy. This was followed closely by 'Variable motor speed adjuster' (RII=0.83); 'On/off toolbox' (RII=0.81) and 'Timers' (RII=0.80) ranked second, third and fourth respectively. Details of the ranking of other strategies is as presented in the Table.

Conclusion

1. Maintenance of the HVAC systems is informed by the following facts in the order of severity; availability of fund, faulty operation of the system and in few occasion it is a normal maintenance routine. The maintenance of the HVAC systems when reported stays as much as four weeks and even more. The routine maintenance of the HVAC systems in most of the Hotels is done in interval of 18months with only few Hotels (such as Immaculate, Bay view Hotel, Ideal Suit, Rock view and City global Hotel) who take less timing of about 7-12months. the most common fault often observed in the HVAC control is 'Control Sensor Faults'; 'faulty Adjusters'; very low 'Control setting' and 'Control settings higher than desired' arranged in the order of how frequent it occurs.
2. The most maintained component of the HVAC system are the chillers. While an overview of the common maintenance check in each of the components are as follows:
    a) the Chillers ("Inspection and adjustment of all operating safety controls", "Lubrication of vane/ linkage/ bearing", "Visually inspection of the chillers

and associated components, for an unusual sound or noise for evidence of unusual conditions" and "Check on the refrigerant level, leak test with electronic Leak detector. If abnormal, trace and rectify as necessary").

b) the Water Pump (Checking all bolts and nuts for tightness and tighten as necessary"; Checking all pump bearings and lubricate with oil or grease as necessary" and "Inspection of all water pumps")

c) Air Handling Units are ("Inspection of all air handling and fan coil unit"; "Checking and cleaning of all the condensate pans, trays and drains"; and "Checking all air filters and clean or change filters as necessary" arranged in their order of severity).

d) the Air Cooled Packages Units and precision Computer air conditioning equipment are: ("Checking electrical terminals and contactors operation and connection for tightness" and "Checking fan and motor mounting brackets)

e) the Ventilation Component ("Tightening of the motor terminals"; "Check starter contacts" and "Checking the tension of all belt drives and adjust as necessary")

f) the Switch Board ("Cleaning and adjusting all switch gear, contactors, relays and associated electrical equipment at intervals not exceeding six months")

g) The Piping System ("Checking all piping system for leaks and repair" and "Checking for damage & deterioration of insulation or sheathings. Rectify as necessary")

Automatic thermostat is a promising energy saving strategy using the HVAC system

References

Abrahamse, W., L. Steg, C. Vlek, and T. Rothengatter (2005), A review of intervention studies aimed at household energy conservation, Journal of Environmental Psychology 25, 273-291.

Adeyemi A. andIbe A (2014). Pattern of Firewoood Exploitation and Utilization in Peri-Urban And Rural Areas of Owerri Zone in Southern Nigeria. *Nigerian Journal of Agricultural and Environment*. 10(3): 113-119

Afram, A.; Janabi-Sharifi, F. Theory and applications of HVAC control systems—A review of model predictive control (MPC). *Build. Environ.* 2014, *72*, 343–355.

Afram, A.; Janabi-sharifi, F.; Fung, A.S.; Raahemifar, K. Artificial neural network (ANN) based model predictive control (MPC) and optimization of HVAC systems: A state of the art review and case study of a residential HVAC system. *Energy Build.* 2017, *141*, 96–113.

Alcala, R.; Benitez, J.M.; Casillas, J.; Cordon, O.; Perez, R. Fuzzy control of HVAC systems optimized by genetic algorithms. *Appl. Intell.* 2003, *18*, 155–177.

Al-Homoud, (2005). M.S. Performance characteristics and practical applications of common building thermal insulation materials. *Build. Envrion.*, *40*, 353–366.

Energy Information Administration, International Energy Outlook 2006, U. S Department of Energy, June 2006

IEA. 2004. Energy Balances for OECD Countries and Energy Balances for non-OECD Countries; Energy Statistics for OECD Countries and Energy Statistics for non-OECD Countries (2004 editions) Paris.

Luis P., Ortiz. J, Pout .C (2008). 'A Review on Building Energy Consumption Information; Energy and building, 40(2008) 394-398

Vvakloroaya V (2014) A review of different Strategies for HVAC energy saving, Energy conversion and Management, Western Sydney University