Assessment of the Variation in the Maintenance of HVAC Component Units and Its Energy Consumption Implication

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Abstract
The proper maintenance of the Heating Ventilation and Air Conditioning (HVAC) system promises various advantages ranging from energy savings, decreasing maintenance costs, prevention of hazardous conditions, increase the service life of HVAC equipment and guarantee thermal comfort for the building's occupants. However, HVAC systems have been multi-component systems, for proper maintenance demands a well-planned and strategic approach of maintenance. To this effect, this paper sought to nature, frequency, and the pattern of maintenance of the components units of the HVAC system and its energy implication using the HVAC installation of Hotel buildings in Owerri. It was pursued through the use of a structured questionnaire administered to 384 respondents comprising of the maintenance officers and facilities managers of the 115 Hotels studied. A total of three hundred and forty-two (342) questionnaires were returned adequately filled. The responses were analyzed using the computer SPSS software version 19. The result revealed among others that: the nature of maintenance is often unplanned with the frequency spanning between 13-18months except at the report of a fault. Also, the most maintained component of the HVAC system is the Air distribution system. This was closely followed by the 'Chillers'; 'Ventilators' 'Piping System'' among others ranked in the order of maintenance preference. Thus, the study recommends among others: Uniformity in the maintenance of all the HVAC component units, the use of an Automatic thermostat as against the common On/off toolbox' in the control of the HVAC system to achieve a definite and lasting control of the energy consumption.

Keywords: Component Unit Maintenance, Energy Implication, , Maintenance of HVAC

Introduction

One of the primary essences of maintenance management in any organization is to reduce or even avoid corrective maintenance by proper planning and implementation of maintenance tasks at the right time. And for multi-component systems like the Heating Ventilation and Air Conditioning (HVAC) system, its maintenance requires a well-planned maintenance decision approach that will help the maintenance officer or facilities manager take expert maintenance decisions (Au-yong et al. 2014).

The Maintenance of HVAC facilities is one of the fundamental activities responsibilities of the facilities manager. HVAC maintenance as an intrinsic part of building maintenance (BM), is a basic requirement to keep HVAC running and prevent any sudden failure that can bring the whole system out of acceptable operating conditions. Some of the reasons why it's expedient to properly maintain the HVAC system include; energy savings, decreasing maintenance costs, prevent hazardous conditions, increase the service life of HVAC equipment, and guarantee thermal comfort for building occupants. However over, time the challenges experienced in troubleshooting HVAC problems is traced to the fact that HVAC systems are configured from basic types of components, such as dampers, fans, valves, and coils, and there are usually multiple instances of the same type of components performing different functions in an HVAC system (Yang & Ergan, 2014).

According to Pérez-Lombard *et al* (2008), there has been the intensification of energy consumption in the HVAC systems, which has now become essential in parallel to the spread in the demand for thermal comfort which is no longer considered a luxury as it used to be. It is the largest energy end-use both in the residential and Public Buildings sectors, comprising heating, ventilation, and air conditioning. Its predominance is obvious compared with other energy end-uses in the building.

The energy consumption of an HVAC system though influenced by the performance and operational parameters of the system also largely depend on the characteristics of the heating and cooling demand along with the thermo- dynamic behavior of the building. The actual load of the HVAC systems is less than it is designed in most operating periods due to building behavior (Vakiloroay,

2014). Therefore, the most important factor that contributes to HVAC energy usage reduction in a given building is proper control of the heating and cooling demand (Jin, 2007).

HVAC systems always suffer from various types of faults, since they have large amounts of equipment, actuators, sensors, and controllers. Knowledge of the ins and out of the HVAC system can help prevent expensive breakdowns and unwanted repairs while keeping the system performing at an optimal level. It is estimated that 10%–40% of the HVAC energy consumption can be reduced by removing faults timely (Schein, Bushby, Castro, & House, 2006). Similarly, studies have shown that in a large physical systems, it's also possible to reduce the costly machine failure, equipment downtime, and decrease revenue by keeping abreast of the most effective and current maintenance techniques

This paper assesses the maintenance of the component units of the HVAC installation because the system is multicomponent with a view of establishing the component given less or more attention and its energy consumption implication. This will enlighten clients and facilities managers on the possible savings that can be made from adequate maintenance of the compartments of the HVAC in Hotels during the operational life of the system given the fact that the efficiency of the new HVAC system can be sustained over time with proper maintenance of the installation. (Boardman *et al*., 2005; Sunikka, 2006). Hence, by improving the maintenance of HVAC installation and ensuring uniformity in the maintenance of the compartment of the installation, a decrease in energy consumption can be actualized. Lowering operation costs for businesses as well as reducing greenhouse gas emissions can be realized. The study covers the Hotels with theOwerri municipal only, residential buildings were not considered.

2.0 Literature Review

2.1 HVAC System Components

The HVAC system is a set of components that work together to provide conditioned air to an occupied space to maintain the desired comfort level (Sugarman 2005) As shown in (Fig.1), the HVAC system is made up of the following: chillers, boilers, hot water pump, piping, pipes, valves, dampers, air handling unit (AHU) (ASHRAE 2012), (Handbook 2009). The composition may vary depending on the type of the HVAC system, however, Fig1 presents some of the major components that concern pretty much all HVAC systems.

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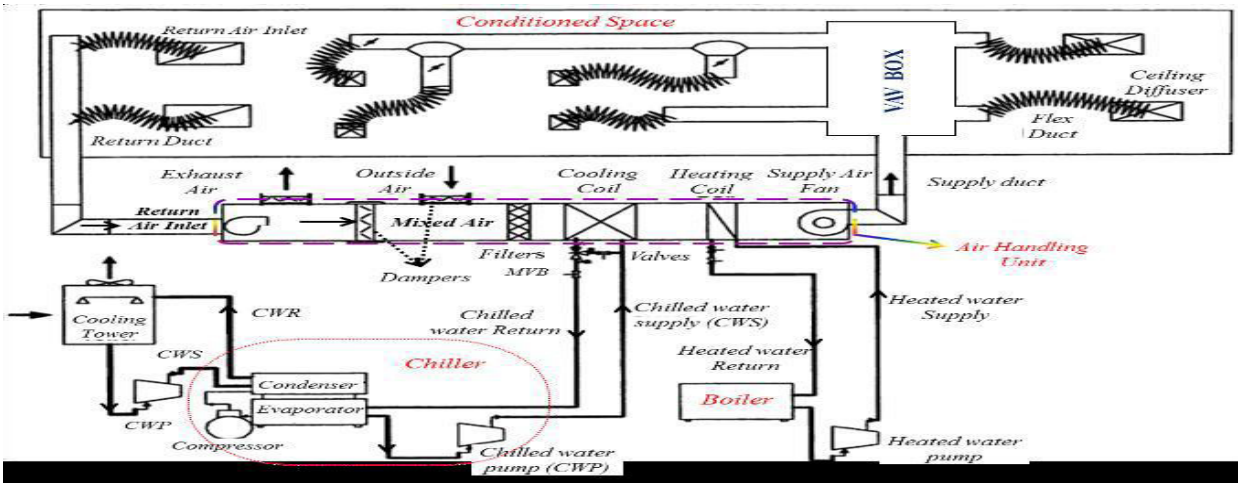

Fig 1: Major Component of the HVAC installation
Source: (ASHRAE 2012), (Handbook 2009).

2.1 The major components of HVAC systems.

A. Thermostat

The temperature sensor on a thermostat indicates when the heater or air conditioner should be running or turned off. It is required that in positioning the thermostat, it must be sited somewhere as far as possible from areas of concentrated temperature difference with the mean temperature of the intended space.

B. Heat Generator

The Heat generator is one of the major components of the HVAC system that is responsible for the generation of heat, by extracting fuel energy inside a furnace/combustion chamber. The hot flue gases will then provide heating for the air or another fluid such as water that will later heat the air entering the conditioned environment.

C. Heat Exchanger

Heat exchangers receive the heat generated in the heat generation unit and transfer it to another fluid. Some control units will activate the furnace or electric heating elements when needed to regulate the air temperature passing through the heat exchanger.

D. Blower

The blower forces air through the heat exchanger into the air ducting that would take the warm air to where it is intended. The blower is driven by an electric motor by a shaft. The modification of the motor speed (varies from one motor to another) can help in adjusting the flow of the air.

E. Condenser Coil or Compressor

The compressor or condenser coil which is normally placed outside is the component that dissipates heat from the warm refrigerant gas to the outside environment and turns it into liquid form. This liquid refrigerant is then taken to the evaporator coil through copper or aluminum tubes. A fan will increase the amount of air flown past the coils and boost the condensation process.

F. Evaporator Coil

The evaporator is located indoors and receives the condensed refrigerant liquid from the compressor. The liquid refrigerant is atomized by spraying nozzles that increase the rate of refrigerant evaporation when it comes to contact with the room's warm air.

G. Air Ducts and Vents

The air is transferred to viaducts to reach different HVAC system components. Good ducting is essential to have high-quality air delivered to the zone. Duct leakage could result in noise when the system is working. In addition, when the air ducting is not in good shape, odor and excess moisture could fill the air.

2.2 Common Maintenance Issues with HVAC Systems

According to Wang, (2013), the maintenance issues, including cooling tower fouling, boiler/chiller fouling, and refrigerant over or undercharge, temperature sensor offset, outdoor air damper leakage, outdoor air screen blockage, outdoor air damper stuck at the fully open position, and dirty filters were investigated in the study he conducted using field survey data and detailed simulation models. The result presented a sample of some of the HVAC maintenance issues (see Table 1) which further prompts the quest to inquire about the impact of maintenance of HVAC parts on energy consumption

Table 1: List of sampled HVAC maintenance issues

Maintenance Type	Maintenance Issues	Impacts
Sensor Calibration	Supply air temperature sensor (SAT) offset	controls, heating, and cooling energy
	Zone temperature sensor offset	
	Outdoor air temperature sensor offset	
Filter replacement D	Dirty filter	pressure drop, fan energy, airflow
Heat exchanger cleaning/treatment	Fouled cooling tower	efficiency
	Chiller: fouled tubes	efficiency
	Boiler: hard water scale	efficiency
	Fouled heating /cooling coil	Efficiency comfort
Mechanical repair	Outdoor air damper leakage	heating and cooling energy
	Stuck outdoor air damper (OAD)	heating and cooling energy
	Clogged OA screen	outdoor airflow is less than 100% during economizer mode thus increasing cooling energy
Refrigerant charge	Chiller: over or under 10% refrigerant charge	efficiency

Source: Wang, 2013

3.0 Research Methodology

This section describes the method adopted for the execution of this study, it entails target population, data collection, and the method of data analysis.

3.1 Population of the Study

The population of this study constitutes all the hotels in Owerri municipal. According to the Jumai Hotel reservation outlook, there are a hundred and sixty-one (161) hotels within Owerri municipal even though are several others within the state.

3.1.1 Sample, Sample size and techniques

In this particular study, the population being studied is the Hotels in Owerri Municipal. There are one hundred and sixty-one (161) hotels within Owerri municipal. Hence the study

However, 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)

For the number of hotels to be evaluated from the population of 161hotels, the formula (1) was applied

$$\mathbf{n= (N/ (1+N (\alpha^2)} \text{.....} (1)$$

Where;

n = the desired sample size

N = the Known Population size

Given that the number of hotels in Owerri Municipal is 161 Hotels, the formula below can be adopted. Consequently, the number of hotels is determined as thus,

N = 162, $\alpha = 0.05$

Hence,

Sample size $n = [(161)/ (1 + 161 (0.05)^2) = 114.7$

Hence = 114.7
Consequently, 115 Hotels were studied, however aside from the Hotels, the specific number of respondents were drawn from the 115 Hotels studied, and to determine the number of respondents, equation 2 (sample size formula for an unknown population (Staff and occupants of the Hotels)

$$N_0 = (z^2pq)/d^2 \cdots\cdots (2)$$

Where;
N_0 = 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'
For this study, a confidence level of 95% was adopted owing to the fact that the questionnaire was geared towards evaluating perception on monitoring
ii) A 95% level of confidence has $\alpha = 0.05$ and critical value of $z\alpha/2 = 1.96$..
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.
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
z = 1.96, d = 0.05 where p = 0.5, q =0.5
N_o = (1.962X0.5X0.5)/ (0.05)2= 384
Thus, after calculating using Cochran's formula for a sample size of 384 respondents

Hence, the study considered 115 Hotels within Owerri Municipal, and as such a minimum of three hundred and eighty-four (384) respondents were drawn from this one hundred and fifteen (115) hotels. Table 3.1 shows the major roads linking the various areas in Owerri Municipal and the corresponding areas along the road where the various hotels for this research were selected.

Table 2: Major Roads Linking Various Areas In Owerri Municipal Where The Hotels Were Selected

S/N	MAJOR ROADS IN OWERRI MUNICIPAL	Area of coverage	Number of hotels to be sampled
1	Port Harcourt Road	Obinze, Avu, Oforola and Ihiagwa, New Owerri	20
2	Naze-Aba Road	Nekede, Agbala and Ulakwo	19
3	Egbu Road	Egbu, Awaka, Ihitta and Emekuku	19
4	Owerri-Orlu Road	Akabo and Obazu, ikenegbu, Prefab, Akwakuma, orlu	19
5	Okigwe – Road	Orji, and Amatta,, Ugwu orji	19
6	Irete-Onisha Road	Orogwe, Amakohia and Ogbaku Egbeada	19
	Total		**115**

Source: Google map, 2018

In choosing the population frame for the respondents and hotels, for this study, a multi-stage sampling technique was employed. In this case, samples are selected in stages (i.e. selection of the areas to be studied first, followed by hotels and then respondents). The respondents are the Staff of the hotels this approach is so in a bid to gather pertinent information concerning the management, scheduling, controls, operations, and maintenance of the HVAC systems. . Nineteen (19) Hotels were selected from each of the five (5) areas identified from the connecting roads within Owerri Municipal with exception of the Port Harcourt Road where twenty (20) were selected as it links more areas.

3.2 Method and Instrument of Data Analysis

The data collected for this study were subjected to various statistical analyses using the computer-based software "Statistical Package of Social Sciences" (SPSS) version 19. The results of the analysis were presented in the form of a table for easy comparison and clear expression of the findings. Also, data obtained through questionnaires were analyzed using the mean score, Relative Importance Index.
The Mean Score was computed using this formula:
Mean-score = $(X_1W_1+X_2W_2+X_3W_3+ \ldots\ldots\ldots\ldots X_nW_n)/N$ .....(3)
Where
W = Weight of answer choice

X = Response count for answer choice
N = Total Numbers of the Respondents

From the computation, the 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 .....(i)
Non-significant constraint factor: MR < 2.5 ..... (ii)

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 was ranked or rated.

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)

$= \frac{\sum fx}{\sum f} \times \frac{1}{k}$ ..... (4)

Where,

∑fx = is the total weight given to each attribute by the respondents.
∑f = is the total number of 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

4.0 PRESENTATION AND ANALYSIS OF QUESTIONNAIRE

A total of three hundred and ninety questionnaires were administered to respondents within the area of study. The percentages of responses are presented in Table 3 below. From the table, it can be gathered that a total of three hundred and forty-two questionnaires were received adequately filled giving a percentage response of 87.7%.

Table 3: Questionnaire administered

Questionnaires	Frequency	Percentage of (%)
Number returned	342	87.7
Numbers not returned	48	12.3
Total	**390**	**100**

Source: Field Survey, (2020)

4.1.6 HVAC Maintenance

Table 4: 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, (2020)

The opinion of the respondents' on the maintenance of the HVAC systems in the hotels and the result is as presented in Table 4. 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 is maintained in an 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 is 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 be 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.

4.1.7 Ranking of Maintenance of the HVAC Components

Table 5: Ranking of Maintenance of the HVAC Components

S/N	Maintenance of the HVAC Components	WEIGHTING/RESPONSE FREQUENCY										
		1	**2**	**3**	**4**	**5**	**(∑f)**	**∑fx**	**MEAN**	**Std**	**RII**	**RANK**
A	**Chillers**											
1	Check refrigerant level, leak test with an 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 the level and condition of oil. If abnormal, trace the fault and rectify it 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/ bearings.	-	04	158	110	70	342	1272	3.72	0.80	0.74	2ND
8	Visually inspect the 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 between pumps and drive motors and rectify as necessary.	92	78	23	135	14	342	927	2.71	1.34	0.54	4TH
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 pans, trays and drains.	78	67	55	97	45	342	990	2.89	1.38	0.58	2ND
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 indicators	90	88	71	77	16	342	867	2.54	1.23	0.50	5TH
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 airflow through the 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 airflow of all fans complies 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	**SWITCHBOARD**											

1	Clean and adjust all switch gear, contactors, relays and associated electrical equipment at intervals not exceeding six months	56	45	112	97	32	342	1030	3.01	1.20	0.60	1ST
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, (2020)

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

The Likert scale result in Table 6 presents the ranking of the maintenance of the HVAC component. From the result in the Table, the HVAC component. is divided into various Components namely: Air Distribution System (with cluster mean value of 3.18 and standard deviation of 1.43), Chillers (with cluster mean value of 3.06 and standard deviation of 1.21), ventilation, Switch Board (with cluster mean value of 3.00 and standard deviation of 1.40), Piping system (with cluster mean value of 2.98 and standard deviation of 1.34), 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), and Switch Board**'** (with cluster mean value of 2.62 and standard deviation of 1.39), all arranged in the order of preference based on the mean value. From the cluster mean value it indicates that of all the various components 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 maintenance of the various component that makes up the HVAC system

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 the 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 an electronic Leak detector. If abnormal, trace and rectify as necessary, Inform department in writing on the rectification (RII=0.66) which ranked second, third and fourth respectively. Details of the ranking of other factors that relate to the chillers as a component of the HVAC system are 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 another 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 "Checking all air filters and clean or change filters as necessary" (RII=0.57) was ranked third. Details of the ranking of another 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 the operation of all modulating and fixed dampers controlling airflow through the 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 procedures are presented in the Table.

g) In the Switch Board, the respondents ranked "Cleaning and adjusting all switchgear, contactors, relays and associated electrical equipment at intervals not exceeding six months" (RII=0.60) as the common practice maintenance procedure of the Switchboard in the Hotels. The details of the ranking of other procedure of the Switchboard 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.

5.0 SUMMARY OF FINDING

The result revealed that there is no planned maintenance of the HVAC systems, and with regards to the maintenance interval; maintenance is only carried out when there are reports of faults, and in few places where there is routine maintenance carried out the interval spans as much 18months in average.

Regarding the pattern of maintenance of the HVAC system components, the common maintenance actions of the components are as presented: for 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 an electronic leak detector. If abnormal, trace and rectify as necessary").

In continuation, the result also revealed the following: 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" as the ranking of the common maintenance check for the water pump as the component of the HVAC system in the Hotels. Still, on the maintenance of the component of the HVAC systems, the result also revealed that the common check is frequently done on the 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.

Still, on the maintenance of the various component of the HVAC system, the result also revealed that the most frequent maintenance checks carried out on 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. Similarly, the most frequent maintenance checks carried on the Air Distributions System are: "Checking the operation of all modulating and fixed dampers controlling airflow through the unit. Lubricate all damper bearings and linkages as necessary".

In furtherance, the study revealed that "Tightening of the motor terminals"; "Check starter contacts" and "Checking the tension of all belt drives and adjust as necessary" are the basic and frequent maintenance often carried out in the Ventilation Component of the HVAC system. It was also discovered that maintenance checks such as: ranked "Cleaning and adjusting all switchgear, contactors, relays and associated electrical equipment at intervals not exceeding six months" is the most common maintenance checks carried out on the Switch Board of the HVAC system as a component. Lastly, on the maintenance of the various component of the HVAC system it was revealed that "Checking all piping system for leaks and repair" and "Checking for damage & deterioration of insulation or sheathings. Rectify as necessary" are the most frequent and reoccurring maintenance checks conducted on the Piping System of the HVAC in the various hotels assessed.

5.1 CONCLUSION

1. The maintenance of the HVAC components is usually not planned and is only carried out at demand or report a fault. Also, in very few Hotels where there is routine maintenance the average interval of the maintenance spans as much as 18months. This account for the energy wastage as the use of the faulty system has energy implication.
2. The pattern of maintenance of the HVAC component system revealed that the most maintained component of the HVAC system is the Air distribution system. this was closely followed by the 'Chillers' (Mean= 3.06); 'Ventilators' (Mean= 3.00) and 'Piping System'' (Mean= 2.98) which ranked second, third and fourth respectively 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 an 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 switchgear, 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")

5.2 RECOMMENDATION

A. Planned maintenance with a shorter routine interval (less than the common 18months interval identified) will help in ensuring proper functionality of all the HVAC system components and also avoid energy wastage. The study strongly discourages maintenance only on a report of a fault on any component of the system.
B. Uniform maintenance attention should be given to all the components of the HVAC system as the entire components are interdependent and need to work together as an entity to avoid energy wastage
C. As much as possible definite attention must be given to the HVAC control component to ensure that there is no form of fault such as bad temperature sensors connection to (Direct Digital Control) DDC and faulty Selector switch connection to DDC at any point in time in hotels.
D. The study also recommends the use of an Automatic thermostat as against the common On/off toolbox' in the control of the HVAC system to achieve a definite and lasting control of the energy consumption of the HVAC systems in the Hotels in Owerri

REFERENCES

ASHRAE, A.H., 2012. HVAC Systems and Equipment, American Society of Heating. *Refrigeration and Air-conditioning Engineers, Atlanta, GA*.

Au-yong, C.P., Ali, A.S. & Ahmad, F., 2014. Preventive Maintenance Characteristics towards Optimal Maintenance Performance : A Case Study of Office Buildings. World Journal of Engineering and Technology, (September), pp.1–6

Cochran, W.G. (1977). *Sampling Techniques.* (3rd.). In Bartlett, J.E., Kotrlik, J.W., and Higgins, C.C. (2001). "Organizational Research: Determining Appropriate Sample Size in Survey Research". *Information Technology, Learning, and Performance Journal*, 19(1), pp 43-50 (Spring).

Jin, G. Y., Cai, W. J., Lu, L., Lee, E. L., & Chiang, A. (2007). Simplified modeling of mechanical cooling tower for control and optimization of HVAC systems. *Energy conversion and management*, *48*(2), 355-365.

Nzukam, C., Voisin, A., Levrat, E., Sauter, D., & Iung, B. (2017). A dynamic maintenance decision approach based on maintenance action grouping for HVAC maintenance costs savings in non-residential buildings. *IFAC-PapersOnLine*, *50*(1), 13722-13727.

Pérez-Lombard L, Ortiz J and Pout C (2008). A review on buildings energy consumption information. Energy and Buildings 40 (394–398)

Schein J., Bushby S.T., Castro N.S., House J.M. (2006), A rule-based fault detection method for air handling units, Energy Build. 38 1485–1492, http://dx.doi. org/10.1016/j.enbuild.2006.04.014.

Sugarman, S.C., 2005. *HVAC fundamentals*, CRC Press.

Sunikka, M. (2006). Energy efficiency and low-carbon technologies in urban renewal. *Building Research & Information*, *34*(6), 521-533.

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

Wang, L, and Hong, T. (2013). Modeling and Simulation of HVAC Faulty Operations and Performance Degradation due to Maintenance Issues. United States: N. p.

Yang, X., & Ergan, S. (2014). Towards a formal approach for determining functions of HVAC components represented in IFC. *Computing in Civil and Building Engineering (2014)*, 633-640.