ISSN No. 1978-3787
Open Journal Systems *2013*

CONFUSION OF REAL SITE IMPLEMENTATION OF VSD UTILIZATION ON WATER PUMP OF A CHILLER PLANT SYSTEM IN OFFICE BUILDING JAKARTA

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Abstratc

The utilization of VSD in centralized air conditioning systems has been applied for years for efficiency purposes. However, found in real implementation has not been really applied as its function yet. This paper will present real site implementation of applying VSD on regulating the motor speed of chilled water pump as its function [1] to control the chilled water flow rate [2] go into the evaporator to let the chiller work as correspond on cooling demand at the actual load level and at its necessary power input. By analyzing some related parameters such as temperature, water pressure and amperes measured and observed to be the raw data then they will show the working performance of chiller impact on energy consumed to be evaluated on its efficiency impact. Found the real implementation at this site the VSD does not look like varying the speed of motor pump as usually applied but more by being set at certain frequency such as 32 Hz. Then mostly the chiller cannot be run as high as cooling demand as running at only about 50-60% as lower chilled water flow rate flowing into the evaporator. Other than that it looks efficiency of refrigeration effect on handling the building load is not good enough as mentioned in catalogue/reference with difficulties on reaching the target chilled water leaving temperature.

Keyword: Variable speed drive (VSD), temperature, chiller efficiency, HVAC System Energy consumption

PENDAHULUAN

The usage of VSD in Centralized Air Conditioning (AC) System has been applying to many buildings for more than 15 years long. The initial goal of VSD utilization is for energy efficiency [2] by reducing energy consumption [3] without sacrificing the comfort [4]. In this paper, the VSD is applied to the chilled water pump of chilled water system installed in office building in Jakarta which is as the place of observation. As the electronic device, VSD installed to control the motor speed by changing the frequency of electric power supplied to motor [1] to control and vary the rotational speed of motor pump [5] in order to control the chilled water flow on following the cooling demand rather than other VSD implementation ever done on following or anticipating big ambient temperature difference as winter season [3]. The chilled water flowing into the evaporator is carrying a load level as the cooling demand.

Figure 1. Chilled Water System

The chilled water – air conditioning system is as shown in Figure 1.

Looked at the real observed, the implementation of the VSD applied to does not seem to be working align on following the cooling demand. It is set to work just on certain frequency instead of working fluctuating. On this condition energy of pump surely reduced [6] but chiller look like cannot work higher on higher cooling demand. More than that the working efficiency on its refrigeration effect of the chiller at its part load relatively not so high as mentioned in catalogue as reference.

This paper present about how much reduction of the chiller working efficiency at its actual working capacity is which is implemented in this way [7]. The observation shows the data measured, observed and analysed on facing the cooling demand in term of energy efficiency [4] [6].

METHOD

The methodology applied to this observation was by direct measurements in the field on some related parameter data such as temperature, pressure amperes and water flow rate. Some of the data are displayed on the controller to complete all the actual running data. Those data will be as raw data related to actual building load.

Some analyses obtained are through several

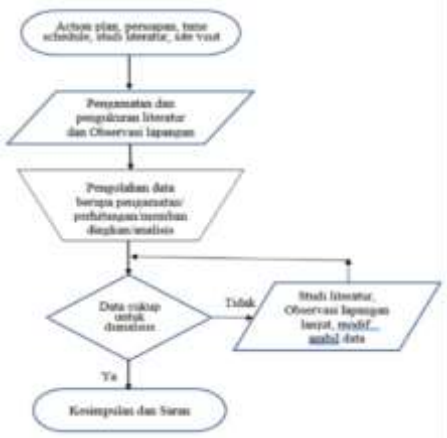


Figure 2. Flowchart of Activities

calculations, referred and compared to the specification of chillers and pump and some references considered on to evaluate the working level of system on overcoming the actual building load. The complete activity is as shown in Figure 2.

Some measurement tool is used such as water pressure gauge to know the discharge pressure of pump and water pressure difference between

inlet to and outlet from chiller to get the estimation of water flow rate based on the catalogue and using water flow meter, ampere clamp meter or as displayed in control display to get the actual amperes and digital thermometer to get the actual air temperature or other temperatures of some parameters displayed in control display.

2.1. Site Observation

The site on which be the place of observation is as office building for banking located in South Jakarta. Then the operational hours are about 10 hours per-day. Chillers and pumps are located on the roof floor of 8-storey office building. As part of airside system there are 2 units for each floor and assisted by an air duct system for air distribution.

The specifications of the chiller and chilled water pump are shown in Figure 2a, Figure 2b, Figure 2c, and Figure 2d [8]

Figure 2a. Specification on Nameplate of Chiller

Brand	YORK
Type	AIR COOLED CONDENSER SCREW CHILLER
Model Number	YCIV1000SA
Refrigerant	R-134a
Electricity	400Volt/3Ph/50Hz
RLA Compressor	230
FLA Motor Fan	3,1 x 12

Standard Efficiency (SE) Models				YCIV1000		YCIV1070		YCIV1180		YCIV1340		YCIV1500	
				Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Chilled Liquid	Liquid Outlet Temperature	Water Outlet	°C	4.4 to 15.6									
		Glycol Outlet	°C	-9 to 15.6									
		Temp. Range	°C	3 to 10									
	Evaporator Flow Rate		l/s	11.4	50.5	15.8	75.7	18.9	75.7	18.9	75.7	18.9	75.7
	Evaporator Pressure Drop		kPa	7.2	92.9	6.2	86.1	11.0	105.1	11.0	105.1	11.0	105.1
	Maximum Water Side Pressure		bar	10									
Ambient Air	Air Entering Temperature		°C	-18 to 52									
	Fan Available Static Pressure	Standard Fans	Pa	10									
		2 Speed Fans	Pa	10									
		High Static Fans	Pa	100									
Maximum Refrigerant Side Pressure			bar	16									
Power Supply Voltage 400V, 3 ~, 50 Hz (nominal)			V	360 to 440									
Recommended Minimum System Water Volume			litres	950		1000		1100		1250		1400	

Figure 2b. Chiller capacity at its temperature

MODEL: YCIV1000S/P

LCWT (°C)	AIR TEMPERATURE ON CONDENSER (°C) 25.0			30.0			35.0			40.0		
	KW	KW	COP	KW	KW	COP	KW	KW	COP	KW	KW	COP
5.0	894.3	219.6	3.7	879.6	248.4	3.3	862.6	282.2	2.9	834.9	316.1	2.5
6.0	919.1	221.4	3.8	903.8	251.2	3.3	886.1	284.0	2.9	856.0	317.2	2.5
7.0	944.5	223.3	3.9	928.6	253.0	3.4	909.9	286.0	3.0	877.4	318.3	2.6
8.0	970.2	225.4	4.0	953.7	255.0	3.5	934.4	287.9	3.0	899.1	319.4	2.7
9.0	996.3	227.5	4.0	979.4	257.0	3.5	959.2	290.0	3.1	921.3	320.5	2.7
10.0	1023.0	229.8	4.1	1005.4	259.2	3.6	984.6	292.1	3.2	943.6	321.7	2.8
11.0	1050.0	232.2	4.2	1031.8	261.5	3.7	1010.4	294.2	3.2	966.5	322.9	2.8
12.0	1077.5	234.8	4.2	1058.6	263.8	3.7	1036.6	296.5	3.3	989.7	324.0	2.9
13.0	1105.6	236.2	4.3	1086.0	266.3	3.8	1063.2	298.8	3.3	1013.3	325.3	2.9

Fig 2c. Working range of Chiller Operation

Chiller working efficiency can be show as [9] mentioned in datasheet model selection below:

Part Load Rating Data				
Load %	Ambient (°C)	Capacity (kW)	Total kW	Unit Efficiency (kW/kW)
100	35.0	1000	286.9	3.345
90	35.0	900.0	260.9	3.451
80	35.0	800.0	228.1	3.507
70	35.0	700.0	198.1	3.535
60	35.0	600.0	165.9	3.616
50	35.0	500.0	136.9	3.575
40	35.0	400.0	114.4	3.496
30	35.0	300.0	86.82	3.579
20	35.0	200.0	58.54	3.400

2.2 Product Specification

Specification of chiller and chilled water pump are obtained from related product literatures. The data related to cooling capacity is observed at its real operational on chilled water flow rate showed [8] as:

Figure 2e. Water flow rate at its Pressure drop

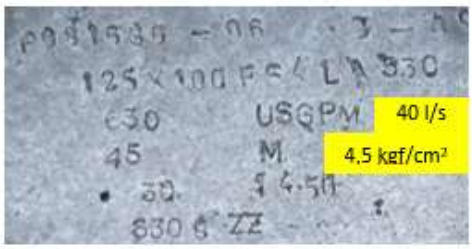


Figure 2f. Nameplate of chilled water pump

RESULT AND DISSCUSION

As seen on the figure 2b about nominal chiller capacity 270TR x 2 unit running, the chilled water temperature is set at 9ºC (48ºF). Figure 2c showing working range of chilled water flow rate (l/s) and its real-actual working water pressure drop along the evaporator shown by Figure 2d blue line as it should be and red line the actual.

Observed at jobsite got that water pressure out from the chilled water pumps going to evaporator of chiller was at about 2 kgf/cm^2 as rated water pressure seen on Figure 3a.

Figure 2d. Chiller Efficiency on its % Loa

Figure 3a. Chilled water pressure out from pump

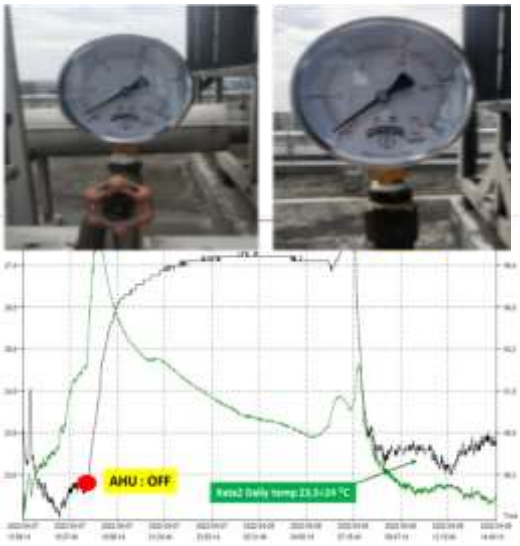


Figure 3b. Water Press in/out to/from chiller

As on reference [6], the actual rated water pressure 2 kgf/cm2 is as controlled by the frequency set of VSD as 32 Hz. Other observation was about electricity as result shown in Figure 3c.

Figure 3c. Power of Chiller and Pump

Working current chiller and pump 275,5 A.
As measured, current of pump was 24 A, so current of chiller only was 251,5 A.
Then the estimated power input was 200 kW. It means working efficiency was 200/150 = 1,33 kW/TR or 2,643 in COP. Compared to Figure 2d [9] shown about 26-30% less.

At the same time chilled water pressure inlet to/outlet from evaporator of chiller and from chiller is about 1.4 kg/cm^2 and 1.1 kg/cm^2 as seen on Figure 3b. That means the water pressure drop working along the evaporator is about 0,3 kg/cm^2 only rather than 0.65 kg/cm^2 as it should be for achieving nominal chiller working capacity.
With 0,3 kg/cm^2 pressure drop and plot to the figure 2d, then got the actual chilled water flow only 25 l/s or 396 GPM instead of the recommendation as about 0.65 kg/cm^2 or 40 l/s or 634 GPM. It means that the chiller was working lower as sensing the lower building load as lower chilled water rate in its evaporator while temperature inlet/outlet were 57.4/48.3 ºF or ΔT = 9.1 ºF.
On the other side observing on airside, got the temperature as representative of actual building load as seen on chart shown by Figure 3c. It was showing that temperature will rise up and down relatively fast on cooling off and on while 23 ºC was as temperature set. Meaning that the cooling demand was still high and need to be overcome.

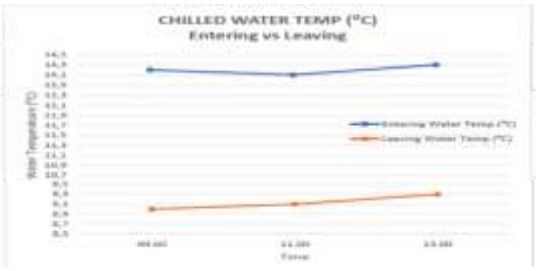


Figure 3d. Room Air Temperature Profile

On other way the building load were matched and mostly it can be exactly covered by those 2 chillers running in order to achieve the target temperature set.

Figure 3e. Chilled water temp inlet vs outlet

Furthermore, discussing about working capacity of chillers based on Figure 3e for chilled water temperature inlet (entering) and outlet (leaving). The basic formula to calculate capacity is as:

$Q\ (Btu/h) = (\dot{V} \times \rho) \times C_p \times (T_{in} - T_{out}) \times 60$ min/hr

$Q\ (Btu/h) = 500 \times \dot{V}\ (GPM)\ X\ \Delta T\ (ºF)$

Q (TR) = (V̇ (GPM) X ΔT (ºF))/24
V̇ : Volume flow rate (USGPM)
P : Density of water (8.34 lb/Gal)
C_p : Specific heat of water (1.0 Btu/lb.ºF) T : Water temperature (ºF)
Q (TR) = (396 x 9.1)/24 = 150.15 TR

It means working capacity is 150TR/chiller while cooling demand to overcome building load as temperature shown on Fig 3d that about 300TR. So % operation of each chiller is only running at almost 60% only or in other words refrigerating effect of evaporator in absorbing the heat is only 60% while cooling demand was higher.

Figure 3e. Water Flow Meter

On estimating chilled water flow rate flowing in evaporator is based on the difference of water pressure drop inlet and outlet and also using water flow meter too.

The water flow rate measured by water flow meter is as range as 11 ÷ 22 l/s or about 285 ÷ 333 GPM/chiller as almost similar observed based on pressure drop.

Then by applying formula above, the working capacity of each chiller is about 125 TR or 50% operation so that total actual building load is about 250 TR or maximum about 270 TR. Meaning that this builing load is slightly similar to nominal capacity of 1 chiller unit.

At this condition working of VSD is set at 32 Hz as seen on Figure 3f.

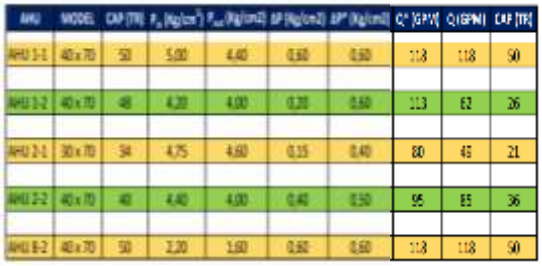
f VSD

Working frequency made by the VSD installed at pump influence the lower speed as formula [6]:

$$Q_2 = Q_1 \left(\frac{N_2}{N_1}\right)$$

So as lower actual working frequency on 32 Hz rather than fluctuating then it controls the motor speed lower as well of the pump N_2 (Rpm), then the flow Q_2 (l/s) become lower too as 25 l/s mentioned on Fig 2d. As this low water flow rate impact on working capacity of chiller at @ 150 TR only. Consenquently total building load should be covered by 2 chillers rather than 1 chiller 270 TR nominal chiller capacity.

Look at air handling units AHU also got bad impact as low working effective of VSD.



AHU	MODEL	CAP (TR)	P_1 (kg/cm²)	P_{out} (kg/cm²)	ΔP (kg/cm²)	ΔP' (kg/cm²)	Q' (GPM)	Q (GPM)	CAP (TR)
AHU 1-1	40 x 70	50	5.00	4.40	0.60	0.60	113	118	90
AHU 1-2	40 x 70	48	4.20	4.00	0.20	0.60	113	82	26
AHU 2-1	30 x 70	54	4.75	4.60	0.15	0.40	80	45	21
AHU 2-2	40 x 70	40	4.40	4.00	0.40	0.50	95	85	36
AHU B-2	40 x 70	50	2.20	1.60	0.60	0.60	113	118	90

Figure 3g. Working performance of AHU

Shown that working performance is lower than the nominal capacity as accordance lower circulating water flow rate that it should be.

CONCLUSION

1. The achievement of room air temperature shows at 23-24ºC as about air temperature set. It means that building load has been covered well at 250-270 TR
2. Seen the VSD work by being set at certain frequency rather than fluctuating is not good enough in efficiency as it made the chilled water flowing at lower flow rate than it should be. So it makes the refrigerating effect of evaporator not enough on correspond the cooling demand as only about 50-60% of its nominal chiller capacity.

3. Other than that, working chiller efficiency is also lower than as mentioned in catalogue [9].

RECOMMENDATION

1. The VSD work controling the chilled water flow looks need to be evaluated and improved to work precisely fluctuating along the cooling demand. [10]
2. The accuracy of sensors related to working operation of VSD such as pressure and temperature sensors need to be evaluated.

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