Feasibility of Saving Energy by Using VSD in HVAC System, A Case Study of Large Scale Hospital in Malaysia

M.M.S. DEZFOULI, S. MOGHIMI, F. AZIZPOUR, S. MAT, K. SOPIAN

Solar Energy Research Institute (SERI), Universiti Kebangsaan Malaysia
43600 UKM Bangi, Selangor,
MALAYSIA.

Email: salehi.solar@yahoo.com

Abstract: This study presents evaluation of energy saving, bill saving, payback period, and avoided emission by using Variable Speed Drive to standard motors in FCUs and AHUs of HVAC system in one of large scale medical centres (UKMMC) in Malaysia. It was found that the energy saving has direct relationship with percentage of speed reduction in drive as by 60% and 10% speed reduction can reach to maximum and minimum amount of energy saving respectively. The best size and amount of payback period, and energy saving, saving cost and emission reduction was found for 60% speed reduction. It has been evaluated that the total energy savings of 4963 KW/h, 917KW/h can be achieved in one year by using VSD with 60% speed reduction for AHUs and FCUs respectively. Also, it has been estimated that amounts of bill saving cost for AHUs and FCUs are US$496,323 and US$ 91,721. The payback periods for AHUs and FCU were 0.5 and 2.6 years.

Key-Words: VSD (Variable Speed Drive) motors, HVAC system, Energy saving, Cost

1 Introduction

Nowadays, due to rising costs of fossil fuels and recourses reduction, producing electrical energy by renewable energy, and reduce of electrical consumption are very important topics on the world. Electric Motors have a large share of the daily energy consumption. Most motors in the commercial sector are used to Air Handling Unit (AHU) or Fan Coil Unit (FCU) in the Heating, Ventilation and Air Conditioning (HVAC) systems [1-4].

AHU is the large metal box type unit as part of one HVAC system which containing blowers, filter, cooling coil, heating coil, damper, and ducts [5, 6]. It is used to produce supply air in various parts of buildings. Depending to cooling load and zone capacity of buildings, structure and the number of AHU components such as number of fans, ducts, and dampers should be design [7-9]. The schematic diagram of AHU is shown in Figure 1 the outside air can mix with return air from room in duct before filtration. Then fan or blower sucks air to send it to heating or cooling coil. Cool or hot air in supply air duct can be divided in different zones. FCU as a part of HVAC system is one device to produce supply air which containing blower, filter and cooling/heating coil. Usually FCUs are installed in the rooms and don't have any ducts whereas supply air from AHU receives to rooms by ducts. The AHU system is more complete and bigger than FCU system; therefore blower motor power (hp) in AHU is much bigger than FCU. To produce comfort condition for special buildings such as hospitals, laboratory, and library in tropical countries, considerable amount of energy is used by AHU and FCU [10]. This large amount of energy used is due to various factors such as high energy consumption of blower, dehumidification, and fresh air usage.

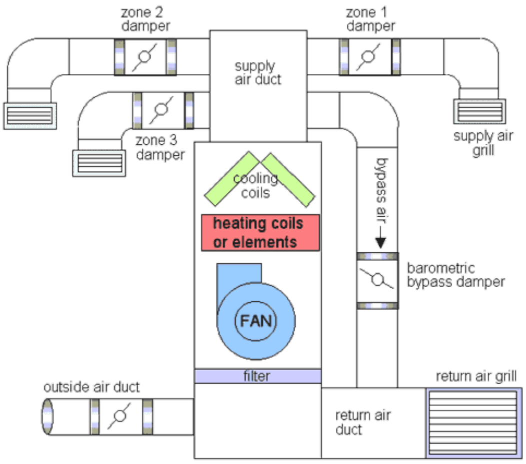


Figure 1: air handling unit diagram

(Source: smarthomeideas.com)

Researches by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) show that approximately 40 % of all energy used in a typical building is for HVAC systems [11]. Design of these systems is based on operation at maximum load while there are some period times that cooling load is less than the maximum load. Therefore, they have inefficient operation during the long periods of time.

Variable speed drive (VSD) is a device that reduces motor electricity consumption about 30–60% by controlling the speed and rotational force of motor for every load condition [12]. One of the most effective technologies applied in recent years is the use of VSDs, on HVAC system induction motors [13]. VSDs are one of the best cost-effective methods to increase efficiency and reduce costs of HVAC systems. These drives prevent wasted energy by precisely matching motor speed with cooling demand, and can dramatically cut power usage. VSDs are one of the most cost-effective ways to maximize efficiency and reduce operating costs. When HVAC system requires less cooling or heating than the maximum load for which it was sized, VSDs allow the equipment to operate at a lower speed. Lower speed equals less energy usage and results in efficient part load operation and reduced operating costs [14]. Therefore one of the methods to reduce energy consumption is reduce of energy consumed motors by using Variable Speed Drive (VSD) technology. On the other hands saving energy by using VSD motors can be one solution to prevent an energy crisis in the all countries.

Many of scientists and researchers have studied on feasibility of VSD to develop HVAC systems in recent years. Nadel et al. [15] investigated energy saving of HVAC system by using VSD. They found that VSDs can save 20-40% of energy in HVAC systems. Almedia et al. [16]carried out estimation of electricity savings potential for application of energy-efficient motors, and variable speed drives in HVAC devices (pumps, fans and compressors). A review study of reduce energy consumption by using VSDs in cooling systems was carried out by Qureshi and Tassou [17]. Thirugnanas et al. [18] have analyzed application of VSDs for motors that operates at very low load (3-16%). They found that there is a potential solution to optimize this kind of motors to avoid energy losses by using variable speed drives. Saidur et al. [19] have studied energy saving and emission reduction analysis for industrial motors in Malaysia. Their results showed that a substantial amount of energy saving, and also emission reduction can be achieved by using VSDs in industrial motors.

This paper presents a study on feasibility of saving energy by using VSDs and replacement to standard motor for HVAC system in UKM Medical Center in Malaysia.

2 Materials and methods

This section explains the case study description, methodology used to calcualte energy savings, cost saving, payback period, and emission reductions by variable speed drives.

2.1 Field of study description

This field study was carried out on AHU and FCU motors of HVAC system in University Kembangaan Malaysia Medical Centre (UKMMC). The UKMMC is the educational hospital of National University of Malaysia established in 1997, located in Cheras, Kuala Lumpur, Malaysia. Malaysia is a tropical country with a hot-humid climate lying between 3° 5´ north and 101° 43´ east. Air temperature reaches at peak at maximum 29°C -34°C as well humidity 70% -90%. Average daily temperature ranges 26°C-27°C. As Figure 2 shows a general view of UKMMC. The building includes different blocks namely clinical block, educational block and residential blocks for doctors and nurses [20-22].

Figure 2: General view of field study (UKMMC)

There are 141 AHUs that each AHU has one standard motor. The minimum, average, and maximum motor power of AHUs are 1, 10, and 30 HP, respectively. Table 1 shows The list of motor specification of AHUs was arranged based on HP of motors, number of units and average annual time usage for each unit (hours). This motors same as traditional electric motors have mainly two states: stop and operate at maximum speed. The energy consumption of motors is based on maximum load even in low load operation. Therefore if the load reduces, significant energy saving can be achieved when the rotational speed of motor is decreased to match with load requirement. The methodology of this study was using VSD system with different speed reduction to energy saving purpose on HVAC in UKMMC.

Table 1: Motor Specification of AHUs

Motor Power (hp)	Number of units	Average Annual time usage for each unit (hour)
1	2	8760
2	5	8760
3	28	7901e
4	15	5641
5	5	7545
5.5	5	6452
7.5	13	6479
10	18	4886
15	33	6442
20	10	4920
25	2	2562
30	4	6088

Table 2 shows specification of FCUs used in the Hospital. Totally there are 879 FCUs in power between 0.029 and 2.5 HP.

Table 2 Motor Specification of FCUs

Motor Power (hp)	Number of units	Average Annual time usage for each unit (hour)
0.029	130	8625
0.033	179	5144
0.066	12	5358
0.067	225	5494
0.068	4	5844
0.17	77	6261
0.25	1	2928
0.4	19	4463
0.5	67	3885
0.6	14	4178
0.67	29	4738
0.7	1	2928
0.9	41	8476
1	75	8216
1.5	4	2928
2.5	1	2928

2.2 Annual Energy Saving

Table 3 shows the Energy saving potential in different speed reduction by using VSD system. By decreasing load and also rotational speed of motor energy saving potential will be increase. The minimum and maximum energy saving potential for VSD application are 22%, and 83% by 10 and 60 % speed reduction respectively.

Annual energy saving for each motor of AHUs and FCUs was calculated by using equation 1.

$$\mathrm{AES} = \mathrm{P} * 0.746 * \mathrm{h} * \mathrm{ESP}$$

where AES is annual energy saving (kWh), P is motor power (HP), 0.746 is the conversion factor from horsepower to KW, h is annual average usage hours, and ESP is Energy saving potential in each average speed reduction (%).

Table 3: Energy saving potential in different speed reduction by using VSD

Average speed reduction	Energy Saving Potential (%)
10	22
20	44
30	61
40	73
50	78
60	83

2.3 Annual Energy Saving Cost

The Annual energy saving cost can be calculated by Eq 2.

$$AESC = AES * Ce$$

where AESC is the cost of Annual energy saving in us$, AES is annual energy saving in kWh, Ce is the Cost of electricity per kWh in us$. For calculating the cost of electricity three years case study bills were considered from 2009 to 2011.it was calculated 0.1 US $ per kWh.

2.4 Simple payback periods

The simple payback can be calculated by dividing incremental cost over annual energy saving cost (Eq 3).

$$simple\ payback = incremental\ cost/AESC$$

2.5 Emission reduction calculation

Saving building energy would be saved power plant energy generation that leads to reduce amount of Co2 and other emissions. Eq 4 shows annual emission reduction of energy saving by applying VSD.

$$\mathrm{ER} = \mathrm{AES} \times \mathrm{EF}$$

where ER is Emission Reduction in kg, EF is Emission Factor in kg.

Table 4 shows emission factor of fossil fuel to generate per unit of electricity. The percentage share of fuel for generating electricity energy in Malaysia is illustrated in Table 5.

Table 4: Emission factor of fossil fuel for electricity generation

Fuels	Emission factor (kg/kWh)			
	CO_2	SO_2	NO_2	CO
Coal	1.18	0.0139	0.0052	0.0002
Petroleum	0.85	0.0164	0.0025	0.0002
Gas	0.53	0.0005	0.0009	0.0005
Hydro	0.00	0.000	0.0000	0.0000
Others	0.00	0.000	0.0000	0.0000

Table 5: Percentage share of fuel used to generate electricity.

Coal (%)	Petroleum (%)	Gas (%)	Hydro (%)
16.76	2.44	53.2	27.6

3 Results and Discussion

3.1 Annual Energy Saving

Table 6 and Table 7 show annual energy saving by applying VSDs in AHUs and FCUs over different speed reduction using Equation 1. The Six amounts of speed reduction from 10% to 60% was considered which minimum and maximum amounts of energy saving was achieved for 10%, and 60% average speed reduction respectively. Therefore, by increasing percentage of speed reduction of VSD, the amount of annual saving energy for AHU and FCU motors will be increased. The minimum amounts of energy saving for AHU and FCU with 10% speed reduction were found 1316, and 243 MW/h respectively. The maximum amounts of energy saving for AHU and FCU with 60% speed reduction were found 4963, and 917 MW/h respectively.

Table 6: Annual energy saving (MWh) over different speed reduction for AHUs

	Average Speed reduction (%)					
	10%	20%	30%	40%	50%	60%
Motor Power (HP)	**Energy saving (MWh)**	**Energy saving (MWh)**	**Energy saving (MWh)**	**Energy saving (MWh)**	**Energy saving (MWh)**	**Energy saving (MWh)**
1	3	6	8	10	10	11
2	14	29	40	48	51	54
3	109	218	302	361	386	411
4	56	111	154	184	197	210
5	31	62	86	103	110	117
5.5	29	58	81	97	103	110
7.5	104	207	287	344	368	391
10	144	289	400	479	512	545
15	523	1047	1451	1736	1855	1974
20	162	323	448	536	573	609
25	21	42	58	70	75	79
30	120	240	332	398	425	452
Total	1316	2631	3648	4365	4664	4963

Table 7 Annual energy saving (MWh) over different speed reduction for FCUs

	Average Speed reduction (%)					
	10%	**20%**	**30%**	**40%**	**50%**	**60%**
Motor Power (hp)	**Energy saving (MWh)**	**Energy saving (MWh)**	**Energy saving (MWh)**	**Energy saving (MWh)**	**Energy saving (MWh)**	**Energy saving (MWh)**
0.029	**5.3**	**10.7**	**14.8**	**17.7**	**18.9**	**20.1**
0.033	**5.0**	**10.0**	**13.8**	**16.5**	**17.7**	**18.8**
0.066	**0.7**	**1.4**	**1.9**	**2.3**	**2.5**	**2.6**
0.067	**13.6**	**27.2**	**37.7**	**45.1**	**48.2**	**51.3**
0.068	**0.3**	**0.5**	**0.7**	**0.9**	**0.9**	**1.0**

0.17	**13.4**	**26.9**	**37.3**	**44.6**	**47.7**	**50.7**
0.25	**0.1**	**0.2**	**0.3**	**0.4**	**0.4**	**0.5**
0.4	**5.6**	**11.1**	**15.4**	**18.5**	**19.7**	**21.0**
0.5	**21.4**	**42.7**	**59.2**	**70.9**	**75.7**	**80.6**
0.6	**5.8**	**11.5**	**16.0**	**19.1**	**20.4**	**21.7**
0.67	**15.1**	**30.2**	**41.9**	**50.1**	**53.6**	**57.0**
0.7	**0.3**	**0.7**	**0.9**	**1.1**	**1.2**	**1.3**
0.9	**51.3**	**102.7**	**142.3**	**170.3**	**182.0**	**193.6**
1	**101.1**	**202.3**	**280.4**	**335.6**	**358.5**	**381.5**
1.5	**2.9**	**5.8**	**8.0**	**9.6**	**10.2**	**10.9**
2.5	**1.2**	**2.4**	**3.3**	**4.0**	**4.3**	**4.5**
Total	**243**	**486**	**674**	**807**	**862**	**917**

3.2 Annual Energy Saving Cost

Table 8 and Table 9 show annual bill saving in US $ and simple payback period for different motor power over different speed reduction percentage. By using VSD in AHU system, the minimum and maximum annual bill saving were 131,555$ and 496,323$ for 10% and 60% speed reduction respectively. The payback period has indirect relation with speed reduction. The VSDs with 10% speed reduction has the maximum amount of payback period (1.8), while VSD with 60% speed reduction has the minimum amount of payback period (0.5).

Table 8: Annual bill saving (US$) and payback period (year) over different speed reduction by using VSDs for AHUs

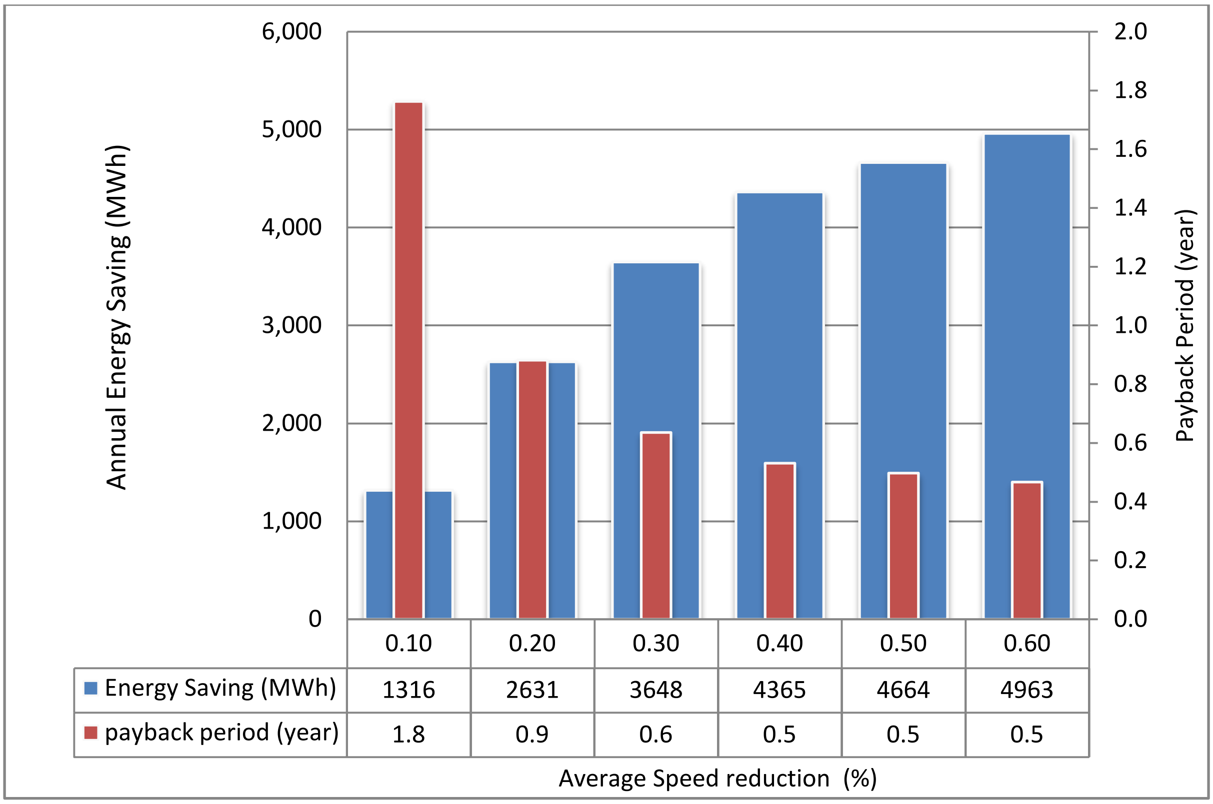
			Average Speed Reduction (%)											
			10 (%)		20 (%)		30 (%)		40 (%)		50 (%)		60 (%)	
Motor Power (hp)	Incremental price (US$)	Subtotal Incremental price (US$)	Bill saving (US$/yr)	Pay back (year)	Bill saving (US$/yr)	Pay back (year)	Bill saving (US$/yr)	Pay back (year)	Bill saving (US$/yr)	Pay back (year)	Bill saving (US$/yr)	Pay back (year)	Bill saving (US$/yr)	Pay back (year)
1	645	1290	288	4.49	575	2.24	797	1.62	954	1.35	1019	1.27	1085	1.19
2	740	3700	1438	2.57	2875	1.29	3986	0.93	4771	0.78	5097	0.73	5424	0.68
3	891	24948	10892	2.29	21784	1.15	30201	0.83	36142	0.69	38617	0.65	41092	0.61
4	1008	15120	5555	2.72	11110	1.36	15403	0.98	18433	0.82	19695	0.77	20958	0.72
5	1125	5625	3096	1.82	6191	0.91	8583	0.66	10272	0.55	10975	0.51	11679	0.48
5.5	1181	5907	2912	2.03	5824	1.01	8074	0.73	9662	0.61	10324	0.57	10986	0.54
7.5	1407	18291	10368	1.76	20736	0.88	28748	0.64	34403	0.53	36760	0.50	39116	0.47
10	1766	31788	14434	2.20	28868	1.10	40021	0.79	47894	0.66	51175	0.62	54455	0.58
15	2235	73755	52331	1.41	104662	0.70	145100	0.51	173645	0.42	185538	0.40	197431	0.37
20	2813	28130	16150	1.74	32300	0.87	44780	0.63	53589	0.52	57259	0.49	60930	0.46
25	3438	6876	2102	3.27	4205	1.64	5829	1.18	6976	0.99	7454	0.92	7932	0.87
30	4142	16568	11990	1.38	23980	0.69	33245	0.50	39785	0.42	42510	0.39	45235	0.37
Total		231998	131555	1.8	263111	0.9	364767	0.6	436525	0.5	466424	0.5	496323	0.5

By using VSD in FCU system, The amount of bill saving has direct relationship with speed reduction, it means by increasing speed reduction percentage, the bill saving will be increased. The minimum and maximum annual bill saving were 24,312$ and 91,721$ for 10% and 60% speed reduction respectively. Trend of payback period with speed reduction in FCU were same as AHU, therefore the VSDs with 10% speed reduction has the maximum amount of payback period (9.9), while VSD with 60% speed reduction has the minimum amount of payback period (2.6).

Table 9: Annual bill saving (US$) and payback period (year) over different speed reduction by using VSDs for FCUs

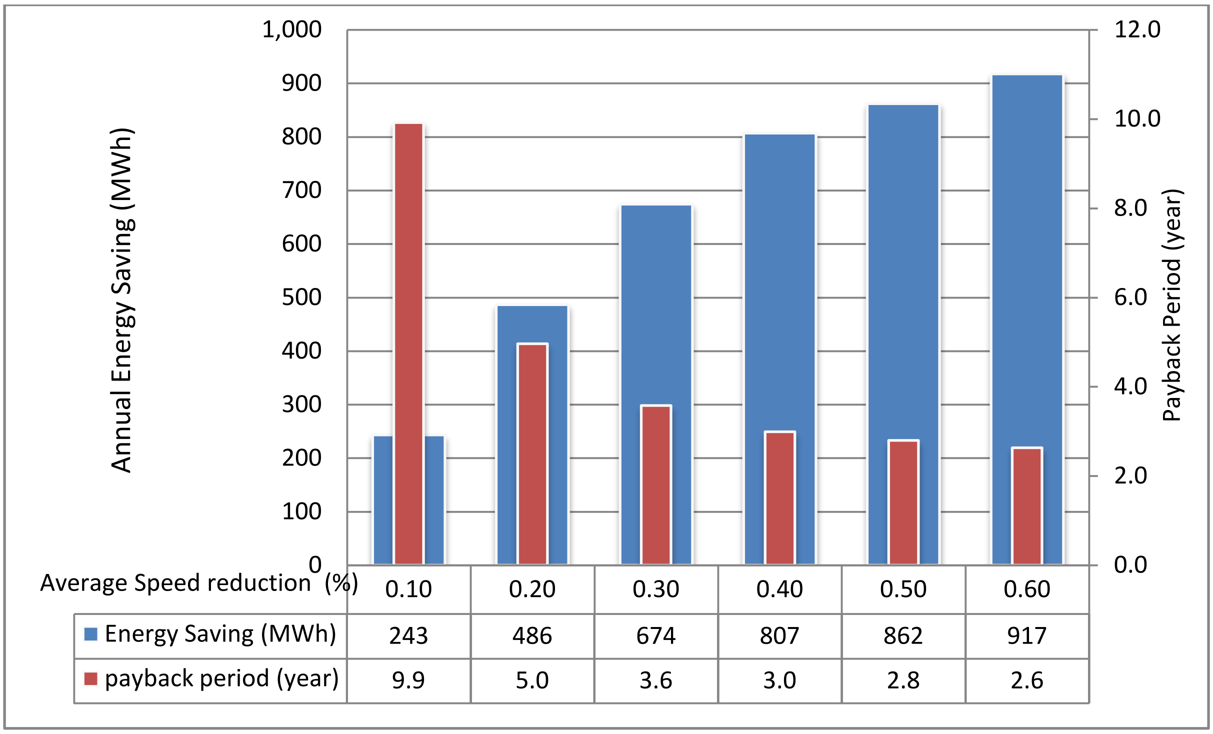
			Average Speed Reduction (%)											
			10 (%)		**20 (%)**		**30 (%)**		**40 (%)**		**50 (%)**		**60 (%)**	
Motor Power (hp)	**Incremental price (US$)**	**Subtotal Incremental price (US$)**	**Bill saving (US$/yr)**	**Pay back (year)**	**Bill saving (US$/yr)**	**Pay back (year)**	**Bill saving (US$/yr)**	**Pay back (year)**	**Bill saving (US$/yr)**	**Pay back (year)**	**Bill saving (US$/yr)**	**Pay back (year)**	**Bill saving (US$/yr)**	**Pay back (year)**
0.029	135	17550	534	32.88	1067	16.44	1480	11.86	1771	9.91	1892	9.28	2013	8.72
0.033	135	24165	499	48.46	997	24.23	1383	17.48	1655	14.60	1768	13.67	1881	12.85
0.066	136	1626	70	23.35	139	11.67	193	8.42	231	7.04	247	6.59	263	6.19
0.067	156	35100	1359	25.82	2719	12.91	3769	9.31	4510	7.78	4819	7.28	5128	6.84
0.068	168	672	26	25.76	52	12.88	72	9.29	87	7.76	92	7.27	98	6.83
0.17	200	15362	1345	11.42	2690	5.71	3729	4.12	4463	3.44	4769	3.22	5074	3.03
0.25	201	201	12	16.69	24	8.34	33	6.02	40	5.03	43	4.71	45	4.42
0.4	360	6840	557	12.29	1113	6.14	1543	4.43	1847	3.70	1974	3.47	2100	3.26
0.5	550	36850	2136	17.25	4273	8.62	5923	6.22	7088	5.20	7574	4.87	8059	4.57
0.6	567	7938	576	13.78	1152	6.89	1597	4.97	1911	4.15	2042	3.89	2173	3.65
0.67	573	16617	1511	11.00	3022	5.50	4189	3.97	5013	3.31	5357	3.10	5700	2.92
0.7	585	585	34	17.39	67	8.70	93	6.27	112	5.24	119	4.91	127	4.61
0.9	625	25625	5133	4.99	10266	2.50	14232	1.80	17032	1.50	18198	1.41	19365	1.32
1	645	48375	10113	4.78	20225	2.39	28040	1.73	33556	1.44	35854	1.35	38152	1.27
1.5	719	2876	288	9.97	577	4.99	799	3.60	957	3.01	1022	2.81	1088	2.64
2.5	815	815	120	6.78	240	3.39	333	2.45	399	2.04	426	1.91	453	1.80
Total		241196	24312	9.9	48623	5.0	67409	3.6	806703	80670	86196	2.8	91721	2.6

Figure 3 and Figure 4 revealed two trends of energy saving and payback period over, different speed reduction in AHUs and FCUs respectively, it is obvious that with more speed reduction percentage the payback period is less. As it shown at Figure 3 by applying VSDs on AHUs with 60 % speed reduction the annual energy saving is 4963 MWh with one year payback period with one year payback period. Figure 4 shows the maximum annual energy saving by applying VSDs on FCUs is belong to 60 % speed reduction with 917 MWh saving and 2.6 year payback period.



Average Speed reduction (%)	0.10	0.20	0.30	0.40	0.50	0.60
Energy Saving (MWh)	1316	2631	3648	4365	4664	4963
payback period (year)	1.8	0.9	0.6	0.5	0.5	0.5

Figure 3: Annual energy saving (MWh) and payback period (year) over different speed reduction by using VSD for AHU



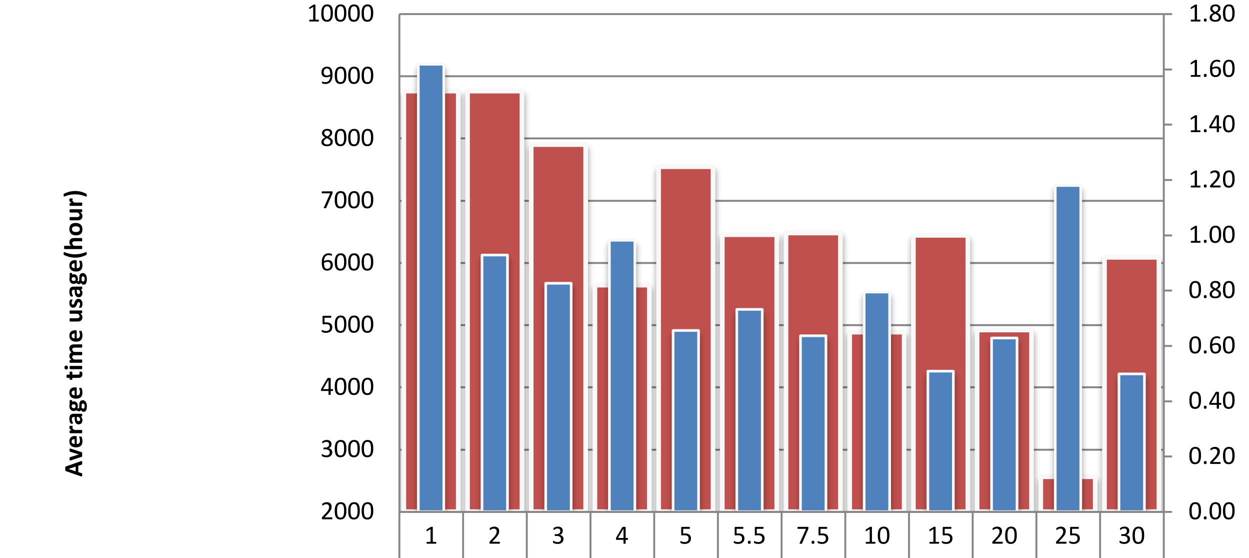
Average Speed reduction (%)	0.10	0.20	0.30	0.40	0.50	0.60
Energy Saving (MWh)	243	486	674	807	862	917
payback period (year)	9.9	5.0	3.6	3.0	2.8	2.6

Figure 4 Annual energy saving (MWh) and payback period (year) over different speed reduction by using VSD for FCUs

The viable result of applying VSD in terms of payback period time in different motors depends on less incremental cost and more time usage that lead to more saving energy and bill. As an example the variety of payback period of applying VSD with 30% average speed reduction over different motor power are illustrated in Figure 3.The best result is 0.8 year belong to motors with 30 HP and it flowed by 15 and 20 HP and the worst case Belongs to 1 HP motors with 4.9 years payback period. While payback period in that range of speed reduction as it shown in Table 5 is 1.3 years.

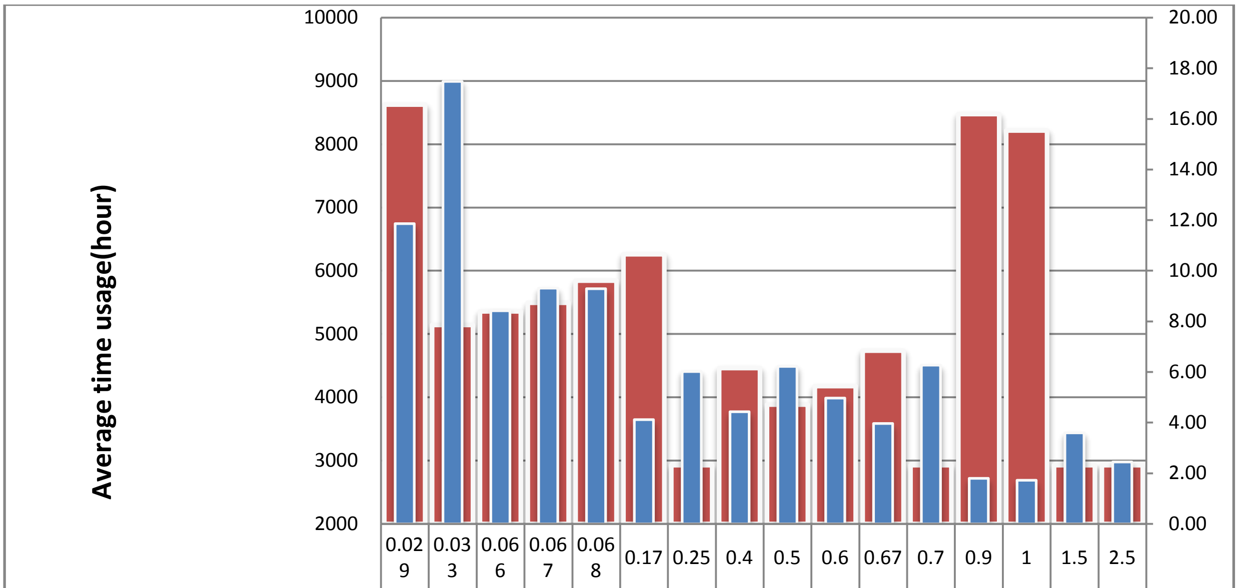
3.3 Annual avoided emission

Annual avoided emission is shown in Table 10. More speed reduction leads to more avoided emission from the environment.



	1	2	3	4	5	5.5	7.5	10	15	20	25	30
Average Annual time usage for each unit(hour)	8760	8760	7901	5641	7545	6452	6479	4886	6442	4920	2562	6088
Pay back (year)	1.62	0.93	0.83	0.98	0.66	0.73	0.64	0.79	0.51	0.63	1.18	0.50

Figure 5 Pay back period and annual time usage over different power of motors in 30 % speed reduction for AHUs



	0.029	0.033	0.066	0.067	0.068	0.17	0.25	0.4	0.5	0.6	0.67	0.7	0.9	1	1.5	2.5
Average Annual time usage for each unit(hour)	8625	5144	5358	5494	5844	6261	2928	4463	3885	4178	4738	2928	8476	8216	2928	2928
Pay back (year)	11.86	17.48	8.42	9.31	9.29	4.12	6.02	4.43	6.22	4.97	3.97	6.27	1.80	1.73	3.60	2.45

Figure 6 Pay back period and annual time usage over different power of motors in 30 % speed reduction for FCUs

Table 10 annual avoided emission (kg/yr)

Speed reduction (%)	Annual amount of avoided emission (kg/yr)			
	CO_2	SO_2	NO_2	CO
10	792615	4574	2302	474
20	1560129	9339	4400	949
30	2162906	12947	6099	1316
40	2588396	15494	7299	1574
50	2765684	16555	7799	1682
60	2942971	17617	8299	1790

4 Conclusion

This paper presents evaluation of energy saving, bill saving, payback period and avoided emission at the one year, by using Variable speed drive in AHU, and FCU in a large medical center in Malaysia. It was found that the applications of VSDs in HVAC system are very useful because the large amount of energy and money can be saved. Amount of energy saving in AHU is more considerable than FCU. Speed reduction percentage is important factor to access to suitable energy saving as 60%, and 10% speed reduction lead to maximum and minimum amount of energy saving, bill saving and avoided emission respectively. The payback period for 60% is less than 10%. Also, It was achieved that:

- By using VSDs in AHU (UKKM) with 60% speed reduction, 4963 KW/h , 496,323$ can be save while the payback period is 0.5 year.

- By using VSDs in FCU (UKKM) with 60% speed reduction, 917 KW/h energy , 91,721$ bill can be save while the payback period is 2.6 years.

Acknowledgements

The authors would like to thank the Solar Energy Research Institute (SERI), University Kembangsaan Malaysia for providing the laboratory facilities and technical support.

References

[1] A. Wemhoff, M. Frank, Predictions of energy savings in HVAC systems by lumped models, *Energy and Buildings*, 42, 10, 2010, 1807-1814.

[2] S. Soyguder, Intelligent system based on wavelet decomposition and neural network for predicting of fan speed for energy saving in HVAC system, *Energy and Buildings*, 43, 4, 2011, 814-822.

[3] M.S. DEZFOULI, Z. HASHIM, M. RUSLAN, B. BAKHTYAR, K. SOPIAN, A. ZAHARIM, S. MAT, A. RACHMAN, Experimental Investigation of Solar Hybrid Desiccant Cooling System in Hot and Humid Weather of Malaysia.

[4] I. Zlatanović, K. Gligorević, S. Ivanović, N. Rudonja, Energy-saving estimation model for hypermarket HVAC systems applications, *Energy and Buildings*, 43, 12, 2011, 3353-3359.

[5] F. Ascione, L. Bellia, A. Capozzoli, F. Minichiello, Energy saving strategies in air-conditioning for museums, *Applied Thermal Engineering*, 29, 4, 2009, 676-686.

[6] Y. Yu, M. Liu, H. Li, D. Yu, V. Loftness, Synergization of air handling units for high energy efficiency in office buildings: Implementation methodology and performance evaluation, *Energy and Buildings*, 2012.

[7] L. Kajtár, M. Kassai, L. Bánhidi, Computerised simulation of the energy consumption of air handling units, *Energy and Buildings*, 45, 2012, 54-59.

[8] S. Ginestet, D. Marchio, O. Morisot, Evaluation of faults impacts on energy consumption and indoor air quality on an air handling unit, *Energy and Buildings*, 40, 1, 2008, 51-57.

[9] M. DEZFOULI, S. MAT, K. SOPIAN, Comparison Simulation between Ventilation and Recirculation of Solar Desiccant Cooling System by TRNSYS in Hot and Humid Area.

[10] D. Licina, C. Sekhar, Energy and water conservation from air handling unit condensate in hot and humid climates, *Energy and Buildings*, 45, 2012, 257-263.

[11] I.M. Shapiro, Energy audits, improvements in small office buildings, *ASHRAE Journal*, 54, 10, 2012, 14-24.

[12] R. Saidur, S. Mekhilef, M.B. Ali, A. Safari, H.A. Mohammed, Applications of variable speed drive (VSD) in electrical motors energy savings, *Renewable and Sustainable Energy Reviews*, 16, 1, 2012, 543-550.

[13] Variable Speed Drives Retrofits for Chillers, Fans, and Pumps, in, *Carrier Corporation*, 2010.

[14] C. PUTZ, Variable Speed Drives on Fan Coils Yield Savings, in: ENERGY, 2006.

[15] S. Nadel, N. Elliott, Overview of programmes to promote energy efficient motor systems in the United States, in: Energy Efficiency Improvements in Electric Motors and Drives, *Springer*, 1997, pp. 365-376. [16] A. de Almeida, P. Bertoldi, W. Leonhard, Energy Efficiency Improvements in Electric Motors and Drives, 1997.

[17] T. Qureshi, S. Tassou, Variable-speed capacity control in refrigeration systems, *Applied Thermal Engineering*, 16, 2, 1996, 103-113.

[18] M. Thirugnanasambandam, M. Hasanuzzaman, R. Saidur, M.B. Ali, S. Rajakarunakaran, D. Devaraj, N.A. Rahim, Analysis of electrical motors load factors and energy savings in an Indian cement industry, *Energy*, 36, 7, 2011, 4307-4314.

[19] R. Saidur, N.A. Rahim, H.W. Ping, M.I. Jahirul, S. Mekhilef, H.H. Masjuki, Energy and emission analysis for industrial motors in Malaysia, *Energy Policy*, 37, 9, 2009, 3650-3658.

[20] S. Moghimi, B. Bakhtyar, F. Azizpour, K. Sopian, C. Lim, S. Mat, E. Salleh, Maximization of Energy saving and Minimization of Insulation Cost in a Tropical Hospital: A Case Study in Malaysia.

[21] F. Azizpour, S. Moghimi, C. Lim, S. Mat, E. Salleh, K. Sopian, A Thermal Comfort Investigation of a Facility Department of a Hospital in Hot-Humid Climate: Correlation between Objective and Subjective Measurements, *indoor and built environment*, 2012. doi:10.1177/1420326X12460067

[22] F. Azizpour, S. Moghimi, S. Mat, C. Lim, K. Sopian, Objective and subjective assessment of thermal comfort in hot-humid region, in: 5th WSEAS international conferences on recent researches in chemistry, biology, invironment and culture, Montreux, Switzerland, 2011, pp. 207-210.