Alternative Education for Comparing the Utilization between Old and New Air Conditioner for Chulachomklao Royal Military Academy Library

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Abstract

This research aims to compare the worthwhile for both old and new air conditioners. Two alternative education investigations are selected, the old air conditioner (Chiller system) is used for 30 years and the new air conditioner is designed for new installation. The types of air conditioner both of Chiller system and VRV system are compared in order to selecting air-conditioning system for optimizing in Chulachomklao Royal Military Academy (CRMA) library. The initial investment, maintenance cost and electricity prices are investigated. For further maintenance cost and electricity prices by using life cycle cost as the fundamental method. In this study, the initial investment of Chiller system is lower than VRV system. The maintenance cost and electricity prices of Chiller system are higher than VRV system. Furthermore, the maintenance cost and electricity prices of old air conditioner are higher than the new air conditioner. For predication, old air conditioner of CRMA library is not worthwhile if it is used more than 15 years ago. Finally, VRV systems can less energy consumption than Chiller system when long term using.

Keywords*:* Air conditioners, Library, Initial investment, Energy consumption.

1. Introduction

Refrigeration is the science of moving heat from a low temperature to a higher one. Refrigeration as the action of cooling requires the removal of heat and discarding it at a higher temperature. The use of refrigeration either directly or as a part of an air-conditioning system is essential to almost every branch of industry and domestic use [1]. In tropical climate countries such as Thailand, air conditioning can account for over 50% of the total electricity consumption in residential and commercial buildings [2]. From the past decade, a split type air-conditioning system typically supplies air conditioned and heated air to a single or a few rooms of a building. The advantages of the split type system include smaller size and flexibility for zoning or heating and cooling individual rooms. The primary disadvantage of split type system is their cost. The chiller air-conditioning system respond to the building efficiency needs by providing the widest variety water and air-cooled industrial and commercial Chillers on the market. The advantages of the chiller system include reducing energy costs and more energy efficient chillers tailored to fit almost any comfort or process cooling application – even heating but initial investment and maintenance cost is higher than split type system.

At present, many researchers in the field of air conditioning are seriously investigated in order to minimizing energy consumption, improving the efficiency, low initial investment and low maintenance cost of the refrigeration and air conditioning systems [3-7]. In this research aims to develop for selecting air-conditioning system in order to installed at Chulachomklao Royal Military Academy (CRMA) library. Subramanyam et al. [3] studied the desiccant wheel integrated air-conditioner for low humidity air-conditioning. The study showed that the proposed system could deliver supply air at much lower dew point temperature compared to the conventional system with a marginal penalty on COP. Its performance was better than the typical reheat system to provide the same low humidity levels. Zhou et al. [5] evaluated the energy performance both of COP and PLR of the VRV air-conditioning system are also examined. The results showed that with average error of 6.36%

for COP and 18.40% for PLR. Furthermore, the energy performance of the VRV system at part-load condition was better than the rated condition. Ghali et al. [7] derived a theoretical model for the transient moisture transfer between a curtain system and the indoor air for the case where the curtain was placed in front of a wall and conduct experiments inside environmental chambers to validate the theoretical model and to test the ability of curtains to moderate indoor humidity. The result showed that the experimental results for the curtain moisture uptake and the relative humidity inside the chamber compared well with the model simulation results. In addition, hygroscopic curtains maintain humidity of less than 65% during part load operation compared to the upper limit of 70% relative humidity when no curtain is used.

The cooled water chiller air-conditioning system or Chiller system was installed in CRMA library more than 30 years (from 1986 until now) but it is continuously maintenance availability. Normally, Chiller system is designed to last about 30 years [8]. The manager of CRMA aims to analyze the worthwhile for both old and new air conditioners. In this study, two alternative education investigations are selected, the old air conditioner (Chiller system) and the new air conditioner is designed for new installation (Chiller system and VRV system).

2. Background theories

The Mollier diagram is a graphic representation of the relationship between air temperature, moisture content and enthalpy - and is a basic design tool for building engineers and designers. By p-h diagram is a figure with a vertical axis of absolute pressure and a horizontal axis of specific enthalpy. It is an important diagram used frequently for a performance calculation of a refrigerating machine. A p-h diagram is made respectively for a specified refrigerant [9].

2.1 Air cooled water chiller air-conditioning system or Chiller system

The chiller system is commonly used in multiple-chiller systems for small to medium sized buildings requiring cooling capacity in the range of 300–1000 tons of refrigeration [10]. In general, individual chillers with different or identical sizes in a multiple-chiller plant operate in parallel to meet the varying cooling load demand, as shown in Fig. 1.

The electricity consumption of Chiller system (Y_1) is shown in Eq. (1) and electricity of Chiller water pump (X_{1a}), Air cooled water chiller (X_{2a}), Fan coil unit (X_{3a}) and Air handling unit (X_{4a}) are shown in Eq. (2-5), respectively.

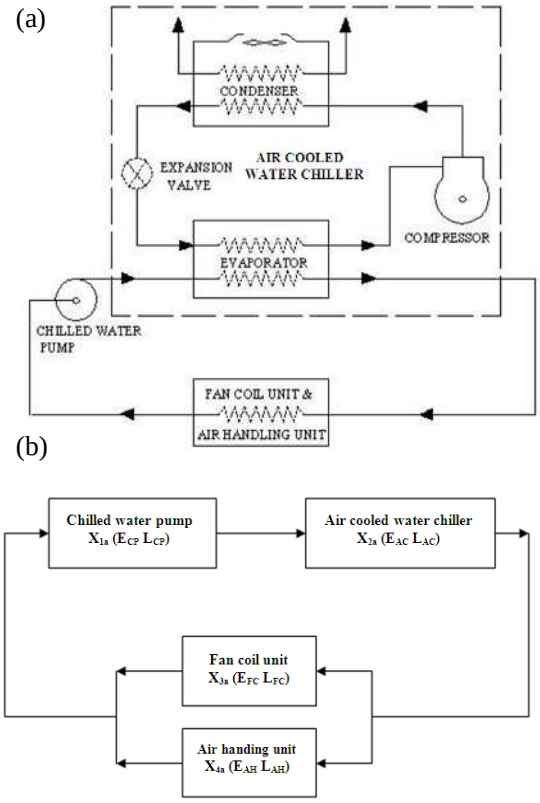


Fig. 1 Chiller system (a) Diagram (b) System analysis

$$Y_1 = [(X_{1a} + X_{2a})\text{Tons}_{\eta H}] + [(X_{3a} X_{4a})\text{Tons}_{FC}] \quad (1)$$

By
$$X_{1a} = E_{CP} L_{CP} \quad (2)$$
$$X_{2a} = E_{AC} L_{AC} \quad (3)$$
$$X_{3a} = E_{FC} L_{FC} \quad (4)$$
$$X_{4a} = E_{AH} L_{AH} \quad (5)$$

E_{CP}, E_{AC}, E_{FC} and E_{AH} are electricity consumption of Chilled water pump, Air cooled water chiller system, Fan coil unit and Air handling unit in kW/Ton, respectively. L_{CP}, L_{AC}, L_{FC} and L_{AH} are efficiency of Chilled water pump, Air cooled water chiller system, Fan coil unit and Air handling unit in %, respectively.

2.2 Variable refrigerant volume air-conditioning system or VRV system

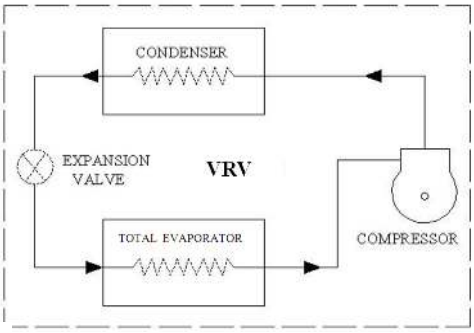
The VRV system is a multi-split type air conditioner for commercial buildings that uses variable refrigerant flow control developed to provide with the ability to maintain individual zone control in each room and floor of a building [11]. VRV system is shown in Fig. 2

The electricity consumption of VRV system (Y_2) is shown in Eq. (6).

$$Y_2 = (X_1 + X_2 + X_{tot})(E_{VRV} L_{VRV})]\text{Tons} \quad (6)$$

X_1, X_2 and X_{tot} are the electricity of Compressor, Condenser, Evaporator. E_{VRV} and L_{VRV} are electricity consumption in kW/Ton and efficiency in % of VRV.

(a)



(b)

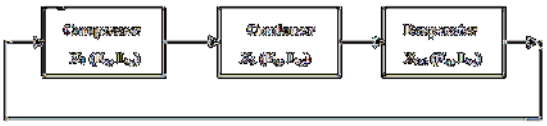


Fig. 2 VRV system (a) Diagram (b) System analysis

3. Evaluation of investment projects

The net return (Eq.(7)) and payback period (n) (Eq.(8)) are the important factor evaluation of investment projects. It is a key to consideration affecting policy- making because economic development is the fundamental force that production system forward [12].

$$\text{Net Return} = (\text{Initial Investment} + \text{Maintenance Cost} + \text{Electricity Prices}) - \text{Return} \quad (7)$$

and

$$n = TS/Y_i \quad (8).$$

where n, TS and Y_i are payback period, initial investment and net return, respectively.

4. Results and discussion

The initial investment, maintenance cost and electricity prices are investigated for Chulachomklao Royal Military Academy (CRMA) library. Two alternative education investigations are selected. The old air conditioner (Chiller system) is used more than 30 years (from 1986 until now). The air-conditioning of CRMA library is used from 8 am to 4 pm (8 hrs per day). The current rate of electricity per unit is specified by Provincial electricity authority report. The Chiller system and VRV system are designed for new installation.

4.1 The initial investment

From CRMA report in 1986, the initial investment of Chiller system is 3,487,900 baths and it is used until now. The Chiller system is installed for 2 floors of CRMA library (225 Tons), 12 for 210,500 BTU and 2 for 78,500 BTU. The new design is calculated both of Chiller system and VRV system. The initial investment of Chiller system and VRV system are shown in Table 4.1 and 4.2. The total initial investment of Chiller system is 7,286,775 Baht (5,318,427 Baht for air conditioner, 572,462 Baht for liquid line and 1,395,886 Baht for electrical equipment and supplies) and the total initial investment of VRV system is 11,612,438 Baht (9,664,212 Baht for air conditioner, 566,610 Baht for liquid line and 1,381,616 Baht for electrical equipment and supplies).

4.2 The maintenance cost

From 1986 until 2016, the maintenance cost of Chiller system from CRMA library or old air conditioner is presented in CRMA report and the maintenance cost of old air conditioner from 2017 until 2035 is predicted, as shown in Fig. 3. From 1986 - 2015, the maintenance cost from the old air conditioner is treated with the straight function and it is treated with polynomial function when 2016 until 2035. The new designs of air

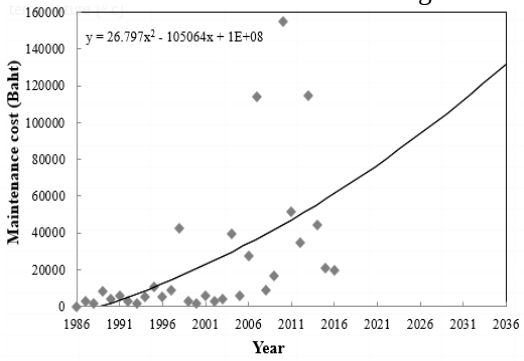


Fig. 3 The maintenance cost of Chiller system from CRMA library

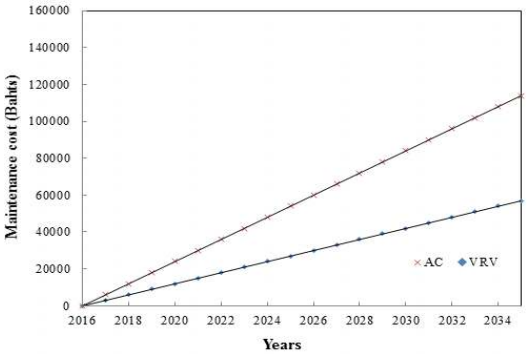


Fig. 4 The maintenance cost of Chiller system and VRV system for the new design

Table 4.1 Total investment cost of Chiller system in CRMA library (New design by Cadet. Satawat Audtoom)

Case	Condition	Number	Material cost (Baths)	Labor cost (Baths)	Remark
1	**Air conditioner**				225 Tons
1.1	EF-1 (120,000 BTU/hrs) Condensing unit	1	178,680	650	
	CU-C (200,000 BTU/hrs) Condensing unit	1	260,390	20,000	
1.2	EF-2 (120,000 BTU/hrs) Condensing unit	10	17,868	6,500	
	CU-C (200,000 BTU/hrs) Condensing unit	1	260,390	20,000	
1.3	EF-3 (18,000 BTU/hrs) Condensing unit	4	107,208	2,600	
	CU-E (79,000 BTU/hrs) Condensing unit	1	102,850	10,000	
1.4	EF-4 (9,000 BTU/hrs) Condensing unit	6	80,406	3,900	
	CU-E (79,000 BTU/hrs) Condensing unit	1	102,850	10,000	
1.5	EF-5 (9,000 BTU/hrs) Condensing unit	6	80,406	3,900	
	CU-E (79,000 BTU/hrs) Condensing unit	1	102,850	10,000	
1.6	EF-6 (36,000 BTU/hrs) Condensing unit	2	107,208	1,300	
	CU-E (79,000 BTU/hrs) Condensing unit	1	102,850	10,000	
1.7	EF-7 (12,000 BTU/hrs) Condensing unit	1	17,868	650	
	CU-E (79,000 BTU/hrs) Condensing unit	1	102,850	10,000	
1.8	EF-8 (30,000 BTU/hrs) Condensing unit	1	44,670	650	
	CU-E (79,000 BTU/hrs) Condensing unit	1	102,850	10,000	
1.9	EF-9 (90,000 BTU/hrs) Condensing unit	1	134,010	650	
	CU-A (100,000 BTU/hrs) Condensing unit	1	148,900	10,000	
1.10	EF-10 (105,000 BTU/hrs) Condensing unit	2	312,690	1,300	
	CU-F (300,000 BTU/hrs) Condensing unit	1	390,580	20,000	
1.11	EF-11 (300,000 BTU/hrs) Condensing unit	2	893,400	1,300	
	CU-F (300,000 BTU/hrs) Condensing unit	2	781,160	40,000	
1.12	EF-12 (6,000 BTU/hrs) Condensing unit	9	80,406	5,850	
	CU-E (79,000 BTU/hrs) Condensing unit	1	102,850	10,000	
1.13	EF-13 (12,000 BTU/hrs) Condensing unit	1	17,868	650	
	CU-C (79,000 BTU/hrs) Condensing unit	1	102,850	10,000	
1.14	EF-14 (30,000 BTU/hrs) Condensing unit	1	44,670	650	
	CU-C (79,000 BTU/hrs) Condensing unit	1	102,850	10,000	
1.15	AHU-1 (480,000 BTU/hrs) Condensing unit	1	714,720	650	
	CU-F (300,000 BTU/hrs) Condensing unit	2	781,160	40,000	
2	**Liquid line**			**572,462**	
3	**Electrical Equipment and Supplies**			**1,395,886**	
	Total			**7,286,775**	

Table 4.2 Total investment cost of VRV system in CRMA library (New design by Cadet. Satawat Audtoom)

Case	Condition	Number	Material cost (Baths)	Labor cost (Baths)	Remark
1	**Air conditioner**				226 Tons
1.1	FC-1 (18,000 BTU/hrs) Floor model	4	69,440	2,600	
	CU-E (79,000 BTU/hrs) Condensing unit	1	102,850	10,000	
1.2	FC-2 (30,000 BTU/hrs) Floor model	2	51,220	1,300	
	CU-E (79,000 BTU/hrs) Condensing unit	1	102,850	10,000	
1.3	FC-3 (24,000 BTU/hrs) Floor model	1	25,140	650	
	CU-E (79,000 BTU/hrs) Condensing unit	1	102,850	10,000	
1.4	FC-4 (18,000 BTU/hrs) Floor model	1	17,360	650	
	CU-E (79,000 BTU/hrs) Condensing unit	1	102,850	10,000	
1.5	EF-1 (120,000 BTU/hrs) Floor model	1	178,680	650	
	CU-C (200,000 BTU/hrs) Condensing unit	1	260,390	20,000	
1.6	EF-2 (12,000 BTU/hrs) Floor model	10	178,680	6,500	
	CU-C (200,000 BTU/hrs) Condensing unit	1	260,390	20,000	
1.7	EF-3 (18,000 BTU/hrs) Floor model	4	107,208	2,600	
	CU-E (79,000 BTU/hrs) Condensing unit	1	102,850	10,000	
1.8	EF-4 (9,000 BTU/hrs) Floor model	1	13,401	650	
	CU-E (79,000 BTU/hrs) Condensing unit	1	102,850	10,000	
1.9	EF-5 (9,000 BTU/hrs) Floor model	1	13,401	650	
	CU-E (79,000 BTU/hrs) Condensing unit	1	102,850	10,000	
1.10	EF-6 (36,000 BTU/hrs) Floor model	1	53,604	650	
	CU-E (79,000 BTU/hrs) Condensing unit	1	102,850	10,000	
1.11	EF-9 (90,000 BTU/hrs) Floor model	1	134,010	650	
	CU-A (100,000 BTU/hrs) Condensing unit	1	148,900	10,000	
1.12	EF-10 (105,000 BTU/hrs) Floor model	2	312,690	1,300	
	CU-F (300,000 BTU/hrs) Condensing unit	1	390,580	20,000	
1.13	EF-11 (300,000 BTU/hrs) Floor model	2	893,400	1,300	
	CU-E (300,000 BTU/hrs) Condensing unit	2	781,160	40,000	
1.14	EF-12 (6,000 BTU/hrs) Floor model	2	17,868	1,30	
	CU-E (79,000 BTU/hrs) Condensing unit	1	102,850	10,000	
1.15	AHU-1 (480,000 BTU/hrs) Floor model	1	714,720	650	
	CU-F (300,000 BTU/hrs) Condensing unit	2	781,160	40,000	
1.16	AHU-2 (480,000 BTU/hrs) Floor model	1	714,720	650	
	CU-F (300,000 BTU/hrs) Condensing unit	2	781,160	40,000	
1.17	AHU-3 (480,000 BTU/hrs) Floor model	1	714,720	650	
	CU-F (300,000 BTU/hrs) Condensing unit	2	781,160	40,000	
2	**Liquid line**			**566,610**	
3	**Electrical Equipment and Supplies**			**1,381,616**	
	Total			**11,612,438**	

conditioners are predicted for the next 20 years (2016 - 2035). The maintenance cost and electricity prices are predicted by using life cycle cost as the fundamental method. The Chiller system and VRV systems for the new design are calculated in Fig. 4. Both of two systems are treated with the straight function. Normally, air conditioner is covered by 1 year limited warranty, after that, the maintenance cost of Chiller system is higher than VRV system. Due to equipment of Chiller system can be costly to build.

4.3 The electricity prices

From 1986 until 2015, the electricity prices of Chiller system from CRMA library or old air conditioner is presented in CRMA report, as shown in Fig. 5. The electricity prices have increased almost straight line. For critical energy, electricity prices have been going up, while over most of that time, the costs of coal and natural gas so the electricity prices of the future (2016 - 2035) are higher than the electricity prices of the past (1986 - 2015).

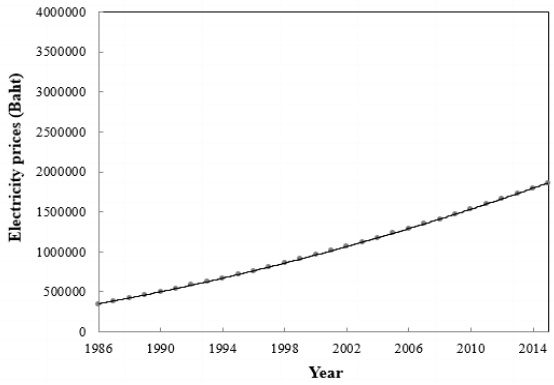


Fig. 5 The electricity prices of Chiller system from CRMA library

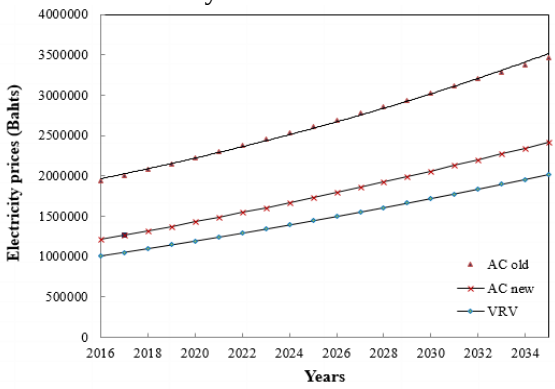


Fig. 6 The electricity prices of Chiller system and VRV system for the new design

Comparison between old air conditioner and new design are shown in Fig. 6. The efficiency of air conditioner is decreased when time progress so the efficiency of old air conditioner is lowest, this causes electricity prices gradually increase. For VRV system, precise individual control and inverter technology minimize energy consumption to deliver optimum energy savings. For the new design, the electricity prices of VRV system are lower than Chiller system. In addition, the electricity prices for the both systems are lower then the old air conditioner.

4.4 Result analysis

From 1986 to 2015, the maintenance cost and electricity prices of CRMA library (old air conditioner) is 750,321 Baht and 30,879,400 Baht, respectively. The total cost is 35,117,621 Baht, it is combined with initial investment, maintenance cost and electricity prices, as shown in Fig. 7. The total for each year gradually increases when time increasing. For Fig. 8, the payback period for 3 years is initial worthwhile. Normally, Chiller system is used as suitable for 20 years, so the pay back period is 8 years and it is optimal used for 10 to 20 years. It can be seen that the total cost is similar trend with payback period. From 2016 until 2035, the total cost for each year is calculated in Fig. 9. The total cost of CRMA library (old air conditioner) is increased with linear function and the total cost is 55,192,645 Baht due to the total cost is maintenance cost and electricity prices. For first year of new installation, the total cost is high because it is composed of initial investment, maintenance cost and electricity prices and the total cost from 2017 to 2035 is maintenance cost and electricity prices. In addition, the total cost for Chiller system and VRV system for the new design (from 2017 - 2035) are calculated at 44,046,459 Baht and 41,865,506 Baht, respectively. From above data, the total cost for each year is slight increase when time increasing. The total cost of Chiller system for the both old and new design are higher than VRV system due to maintenance cost and electricity prices of VRV system are lower than Chiller system. By VRV system is an air conditioner for commercial buildings that uses variable refrigerant flow control developed with the ability to maintain individual zone control in each room and floor of a building. In order to selecting air-conditioning system for optimizing in CRMA library, the types of air conditioner both of Chiller system and VRV system are compared. For 2016 to 2035, the total costs of three systems (Chiller system (old and new design) and VRV system) are predicted in Fig. 10. For air conditioner is used for 5 years,

the total cost of CRMA library (old air conditioner) is lowest, because initial investment conditioner. Furthermore, VRV system is worthwhile for the long time using; due to

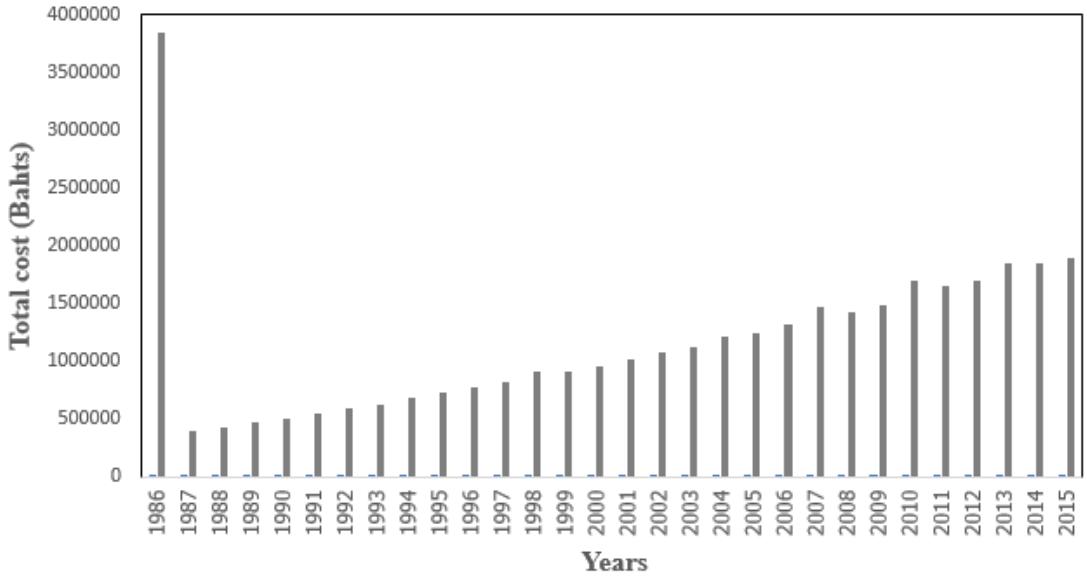


Fig. 7 The total cost of Chiller system from CRMA library from 1986 to 2015

Fig. 8 Payback period of Chiller system from CRMA library from 1986 to 2015

system and VRV systems can less energy consumption. From is not considered. The total cost of VRV system is higher than Chiller system for the new installation because of initial investment. The total cost is similar trends when air conditioner is used for 10 years and the new installations are worthwhile when it is used more than 15 years. From predication, old air conditioner of CRMA library is not worthwhile if it is used more than 15 years ago. Due to the maintenance cost and electricity prices of old air conditioner are higher than the new air

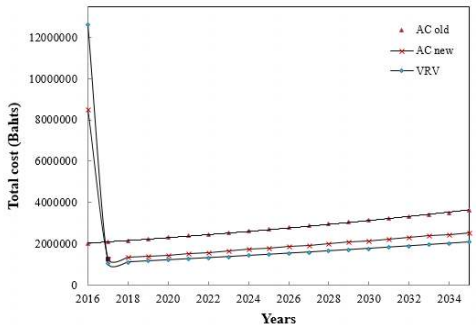


Fig. 9 The total cost of 3 air conditioner systems

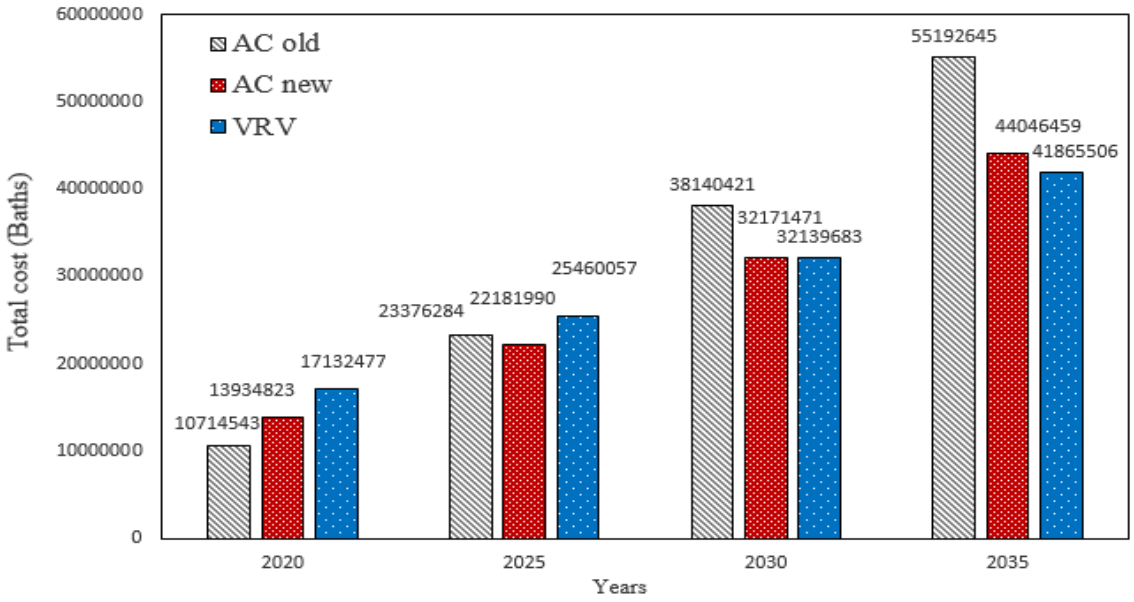


Fig. 10 The total cost of three air conditioner systems in various times

maintenance cost and electricity prices of VRV system is lower than Chiller system and VRV system can less energy consumption. From above data, the old air conditioner is not optimal used more than 15 years. For the new installation, Chiller is optimal used between 10 – 20 years and VRV system is worthwhile for new air conditions for CRMA library with more than 15 years.

5. Conclusion

In this research aims to analyze the worthwhile for both old and new air conditioner. For the old air conditioner (Chiller system), the maintenance cost and electricity prices are high when difference time. For the new designed, the initial investment of VRV system is lower than Chiller system but the maintenance cost and electricity prices of VRV system is lower than Chiller system with more than 15 years. Furthermore, the total cost of VRV system is lower than Chiller system. For the long term, VRV system is the worthwhile for new air conditions for CRMA library. The idea behind this work can be used as guidance for special design of air conditioner of CRMA library in the future.

6. Acknowledgement

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