

# **Integrating Economic Analysis in Decision Making Process: A Case Study of a Steam Absorption Chiller in a Malaysian Gas District Cooling Plant**

**\*Isra Abbasi**

*Universiti Teknologi PETRONAS*

**Zulkipli B Ghazali**

*Universiti Teknologi PETRONAS*

**Mohd Amin Bin Abd Majid**

*Universiti Teknologi PETRONAS*

**Shahirul Fahizam Hussain**

*Makhostia Sdn Bhd*

\*Universiti Teknologi PETRONAS, Bandar Seri Iskandar,  
31750 Tronoh, Perak, Malaysia  
Email: msc.isra@gmail.com

## **ABSTRACT**

This paper highlights the integration of economic analysis in business decision making process. A Gas District Cooling Plant is proposing for the replacement of two existing units of Steam Absorption Chillers (SAC) with two new units. The new units of SAC will improve the plant efficiency and increase the plant capacity. As the proposal involves huge capital outlay, economic justification is central in the decision making. Employing incremental analysis between the new and existing SAC, economic models are used to evaluate the present worth, payback period, rate of return and sensitivity of the proposal to changes in initial investment, annual cost savings, net revenue gain and salvage value.

**Keywords:** Gas District Cooling Plant, Investment Balance Diagram, Net Present Worth, Payback Period, Rate of Return, Sensitivity Analysis, Steam Absorption Chiller

## **1. INTRODUCTION**

Economic analysis supports rational business decision making by determining the best selection among alternatives course of action. Through the link of economic theory and decision sciences, optimal solution to business decision problems can be generated.

A case in point is a proposal to replace two existing units (Unit A & B) of Steam Absorption Chiller (SAC) with two new units of SAC at a Gas District Cooling (GDC) Plant located in University Technology PETRONAS (UTP), Malaysia. The new SAC units will improve the plant efficiency and increase the plant capacity to meet additional demand. As the proposal involves huge capital expenditure, economic justification is accorded primary consideration in the decision making.

## **2. PROBLEM STATEMENT**

The existing plant capacity is able to meet the current demand of chilled water for UTP cooling system. However this installed capacity will not be able to cope up with the future

demand with affect from 2015. This situation is clearly depicted in the following paragraphs.

The GDC Plant located inside UTP is one among the four GDC Plants (KLIA, KLCC, PJ and UTP GDC Plant) operated in Malaysia under the flag of PETRONAS. UTP GDC Plant is the combination of gas district cooling and cogeneration. It is the primary source of electricity supply and chilled water supply to the university with Tenaga Nasional Berhad (TNB) as backup resource for electricity supply, whereas chilled water supply solely depends only on GDC plant (Rangkuti, 2006). The chilled water supply for university usage and in plant usage is mainly dependent on four SACs, four electric chillers (EC) and a single thermal storage tank (TES) (Ameary, 2013, Amar, 2011 & Yaziz, 2011). Figure 1 shows existing chilled water generation system that has total available capacity of 3930 RTh. Considering heat transfer loss of 3.51 %, the total available capacity of chilled water generation system reduces to 3792 RTh. This number reduces further to 3592 RTh once TES tank has been discharged (after 7.5 hours of its usage).

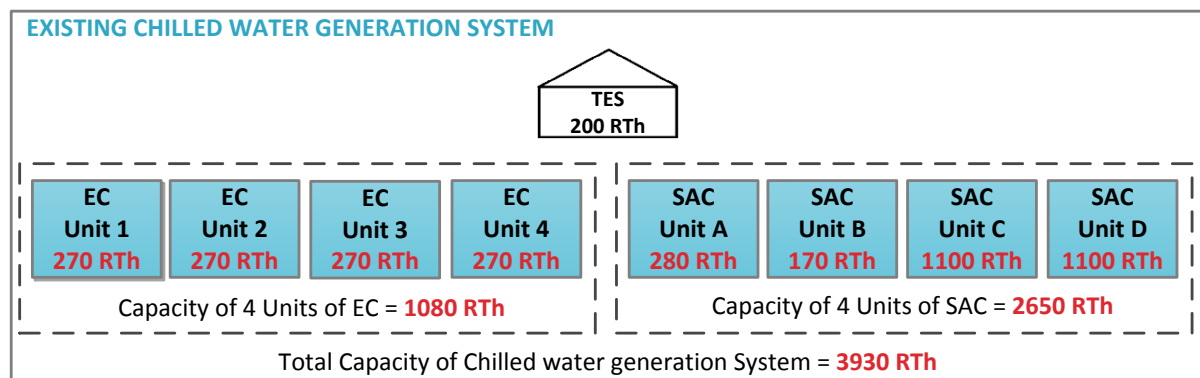


Figure 1: Existing Chilled Water Generation System

$$\text{Available Capacity of Existing System} = [(280 + 170) \text{ SAC (A, B)}] + [(2 \times 1100) \text{ SAC (C, D)}] + [(4 \times 270) \text{ EC}] + [(200) \text{ TES}] = 3930$$

$$\text{Capacity after 3.51\% Heat Loss} = 3930 - (3930 \times 0.0351) = 3792$$

$$\text{Capacity after TES has been discharged} = 3792 - 200 = 3592$$

At present with increasing number of academic activities and buildings constructed in UTP, the demand of chilled water is increasing rapidly. Based on Distributed Control System (DCS) readings, average load demand is recorded to be 3600 RTh for 2012 and 2013, whereas peak load demand is 4393 RTh in 2012 and 3900 RTh in 2013. Higher peak load demand in 2012 is mainly due to huge number of events conducted on campus in that year.

Currently a new Research and Development (R&D) building is under construction in UTP campus and is expected to be commissioned in 2015. Based on information gathered from the consultant of the new building, 1000 RTh will be required to air-condition the new building. Hence, it is anticipated that the average and peak load demand in 2014 will remain same as that of 2013 because the new building is still under construction. However, both peak and average load demand will increase by 1000 RTh in 2015 as the new R & D building will be ready by that year. Hence to ensure future demands are met, it is essential to analyze the available capacity of existing chilled water generation system and assess whether the system can cater for the future requirement. For further illustration, the load demands from 2012 to 2015 are tabulated in Table 1.

Table 1: Existing Chilled Water Generation System

Load Demand	2012	2013	2014	2015
	(Recorded)		(Predicted)	
Peak (RTh)	4393	3900	≈ 3900	≈ 4900
Average (RTh)	3600	3600	≈ 3600	≈ 4600

As shown in Figure 1, the available capacity of existing system is 3792 RTh, which reduces further down to 3592 RTh after TES has been discharged. The average load demand in 2014 is predicted to be 3600 RTh as given in Table 1, which is just close to what the existing system can produce. However the peak load demand in the same year is exceeding the available capacity with a small but noticeable difference of 108 RTh as shown in Figure 2. This difference increases further to 308 RTh after 7.5 hours usage of TES tank.

Furthermore, it is expected that present system of SAC (if remain unchanged) will considerably fail to meet both average and peak demand in 2015. The average demand in 2015 is exceeding the available capacity of existing system by difference of 808 RTh and this difference increases further to 1008 RTh after 7.5 hours of TES usage as illustrated in Figure 3. Similarly, the peak demand is also exceeding available capacity with difference of as high as 1308 RTh. From Figure 2 and Figure 3, it is clear that existing chilled water generation system is unable to meet the future demands.

Hence to cater the increasing load demands in 2015, it is proposed to replace existing two units of SAC (Unit A & B) with two new units of SAC as shown in Figure 4. The two new units of SAC cost RM 13 Mil that includes installation cost. The existing two units (A & B) can be sold for RM 4800. The proposed system is able to produce 5770 RTh (after considering heat loss) which will be more than sufficient to fill the future demands. With 330 operating days in a year and 12 operating hours in a day, the potential annual income from the proposed system is estimated at RM 11.84 Mil. Whereas the potential annual income of existing system is estimated at RM 9.266 Mil. Hence the increment in revenue due to proposed replacement is estimated to be RM 2.574 Mil.

Total Estimated Revenue of New Proposed System:

$$\left(\frac{4600}{hr}\right)\left(\frac{3960}{yr}\right)\left(\frac{RM\ 0.65}{RT}\right) = \frac{RM\ 11,840,400}{yr}$$

Total Revenue of Existing System:

$$\left(\frac{3600}{hr}\right)\left(\frac{3960}{yr}\right)\left(\frac{RM\ 0.65}{RT}\right) = \frac{RM\ 9,266,400}{yr}$$

$$\Delta = RM\ 11,840,400 - RM\ 9,266,400 = RM\ 2,574,000$$

Even though a sound increment in revenue is expected from the proposed system but the economic viability and feasibility of the proposed replacement have to be evaluated before making a final decision.

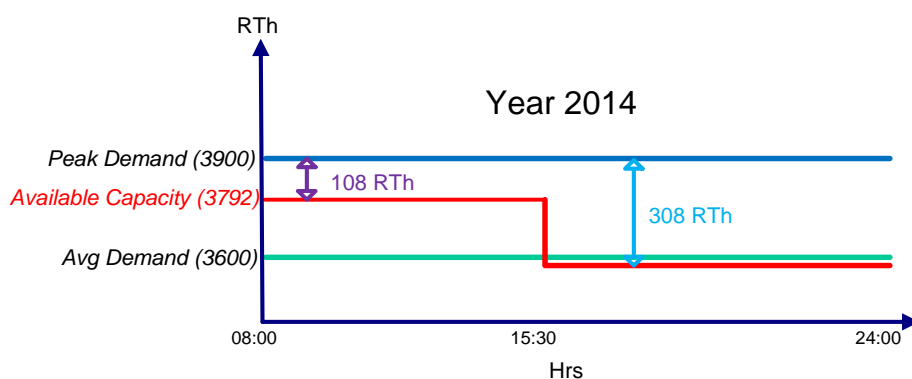


Figure 2: Available Capacity of Existing System & Load Demand for 2014

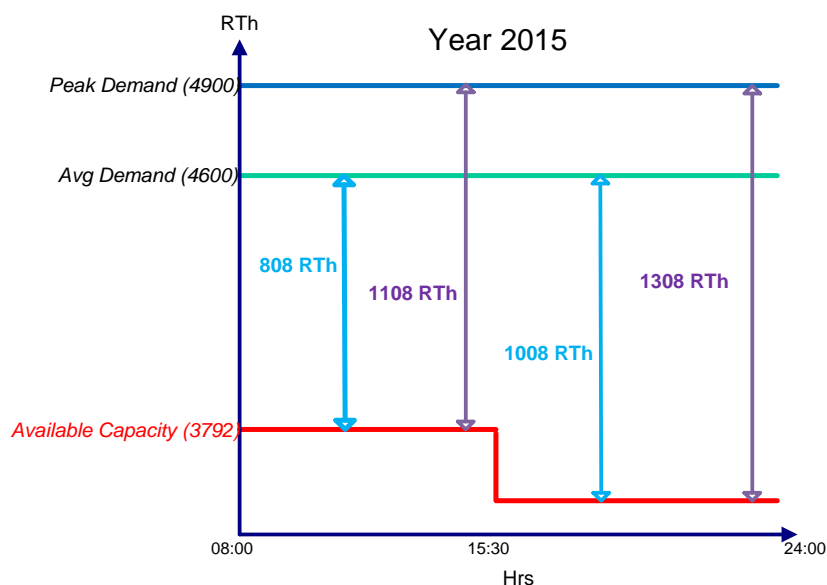


Figure 3: Available Capacity of Existing System & Load Demand for 2015

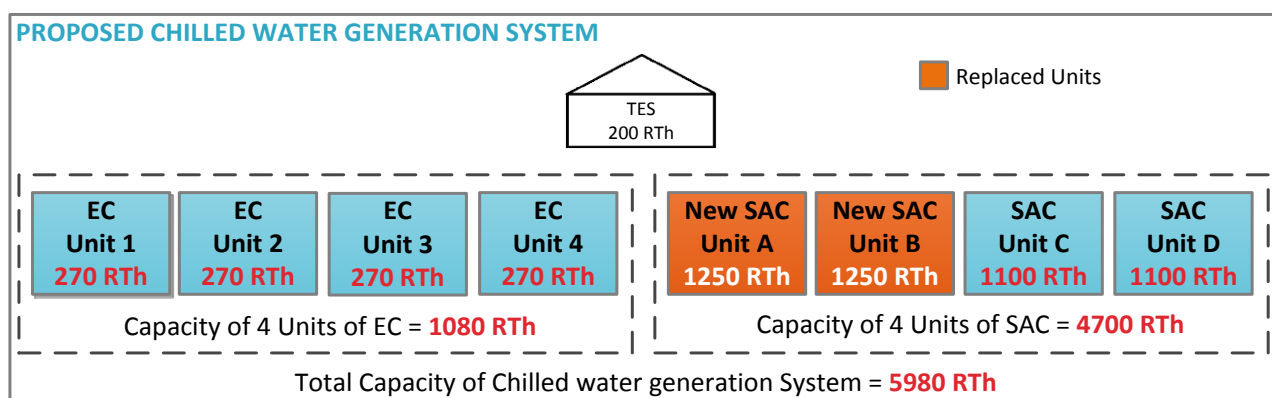


Figure 4: Proposed Chilled Water Generation System

### 3. ECONOMIC MODEL

The economic models that are commonly employed to assess the economic feasibility of capital investment in business organizations include net present worth, payback duration, rate of return, investment balance and sensitivity study (Ghazali, 2011).

#### 3.1. *Net Present Worth*

$$PW = \sum_{k=0}^N F_k (1+i)^{-k} \quad (1)$$

Where  $i$  = minimum attractive rate of return set by the company

$k$  = compounding period (0, 1, 2, 3 . . . N)

$F_k$  = future cash flow at the end of period  $k$

$N$  = number of compounding periods in study period

#### 3.2. *Discounted Payback Period*

This is an assessment of a minimum duration (years) for the project to breakeven. It also represents the project's liquidity riskiness (Sullivan, 2011). Discounted payback period  $\theta$  (where  $\theta \leq N$ ) is calculated with the consideration of time value of money using equation (2).

$$\sum_{k=1}^{\theta} (R_k - E_k)(P/F, i\%, k) - I \geq 0 \quad (2)$$

Where  $R_k$  = cash inflows in period  $k$

$E_k$  = cash outflows in period  $k$

$I$  = the capital investment made at the present time

$\theta$  = the smallest value that satisfies the equation

$i\%$  = the MARR,

$k$  = the number of year

#### 3.3. *Internal Rate of Return*

IRR calculates the rate of return that equates the equivalent worth of an alternative's cash inflows to the equivalent worth of cash outflows (). IRR is  $i'$  %, using the PW formula as given in (3).

$$PW = \sum_{k=0}^N R_k (P/F, i'\%, k) - \sum_{k=0}^N E_k (P/F, i'\%, k) = 0 \quad (3)$$

Where  $R_k$  = net revenues or savings for the  $k$ th year

$E_k$  = net expenditures including investment costs for the  $k$ th year

$N$  = project life (or study period)

Note:  $i' \geq \text{MARR}$  for the proposal to be accepted.

#### 3.4. *Sensitivity Analysis*

This analysis examines the impact of any changes of the cash flow estimates to the proposal. The impact is illustrated through a two-dimensional plot of PW against percentage changes of any estimate of concern namely investment, revenues, expenses, and project life to name a few.

#### 4. RESULTS & ANALYSIS

##### 4.1. Estimates of Costs & Revenues

The estimates of investment cost and up front salvage value for proposed system are given in Table 2. The estimates of annual costs and annual revenues for existing and proposed system are given in Table 3. The proposal is estimated for 10 years useful life.

Table 2: Investment Costs for Proposed System

Activities	Cost (RM Mil)
Capital Investment for two units of SAC	-10
Installation Cost	-3
Sale of 2 Old units of SAC	0.0048
<b>Total</b>	<b>-12.9952</b>

Table 3: Annual Costs & Revenue for Existing & Proposed System

Activities	Existing System Cost (RM Mil)	Proposed System Cost (RM Mil)	Cost Savings (RM Mil)
Annual Electricity Cost for 4 SACs	0.936 (0.234 x 4)	0.936 (0.234 x 4)	0
Annual Water Cost for 4 SACs	0.72 (0.18 x 4)	0.72 (0.18x 4)	0
<b>Annual Energy Cost</b>	<b>1.656</b>	<b>1.656</b>	<b>0</b>
Annual Cooling Tower (CT) Servicing for 2 CTs	0.05 (0.025 x 2)	0.05 (0.025 x 2)	0
Annual SAC Tube Cleaning for 4 chillers	0.06 (0.015 x 4)	0.06 (0.015 x 4)	0
Annual SAC Chemical Cleaning for 4 chillers	0.1 (0.025 x 4)	0.06 (0.015 x 4)	0.04
<b>Annual Servicing Cost</b>	<b>0.21</b>	<b>0.17</b>	<b>0.04</b>
Annual CT Preventive Maintenance (PM) (Salary + Consumables)	0.36 (0.18 x 2)	0.048 (0.024 x 2)	0.312
Annual CT Corrosive Maintenance (CM)	0.06 (0.03 x 2)	0.02 (0.01 x 2)	0.04
Annual Repair Cost for Unit A & B	0.08 (0.04 x 2)	0.02 (0.01 x 2)	0.06
<b>Annual Maintenance Cost</b>	<b>0.5</b>	<b>0.088</b>	<b>0.412</b>
<b>Total Annual Cost</b>	<b>2.366</b>	<b>1.914</b>	<b>0.452</b>
Annual Revenue from Chilled Water Production	9.266	11.840	-
<b>Increment in Annual Revenue</b>			<b><math>\Delta = 2.574</math></b>
<b>Total Annual Income (Revenue-Cost)</b>	<b>6.9</b>	<b>9.926</b>	<b>3.026</b>

#### 4.2. Cash Flow

The cash flow throughout the life cycle of the proposal is given in Table 4.

Table 4: Net Cash Flow

Cost (RM Mil)	0	1	2	3	4	5	6	7	8	9	10
Capital Investment	-10										
Installation Cost	-3										
Annual Energy Cost Savings							0				
Annual Service Cost Savings							0.04				
Annual Maintenance Cost Savings							0.412				
Increment in Annual Revenue							2.574				
Salvage Value	0.0048										
Net Cash Flow	-12.995						3.026				

#### 4.3. Net Present Worth

Net Present Worth (PW) = - RM 12.99 mil + RM 3.026 mil (P/A, 10%, 10)  
 = - RM 12.99 mil + RM 3.026 mil (6.1446)  
 = + RM 5.604 million

Since PW (i=MARR=10%) is positive, this project is economically justified.

#### 4.4. Discounted Payback Period

Table 5 gives the computation of discounted payback period. The proposed investment can be recovered in 6 years, taking into consideration MARR of 10 % per annum.

- Discounted Payback Period,  $\theta$  = Year 6.
- The proposal is attractive by industry standard.

Table 5: Computation of Discounted Payback Period

Year	Net Cash Flow RM Mil	PW (i = 10%) RM Mil	Cumulative PW (i = 10%) RM Mil
0	-12.99	-12.99	-12.99
1	3.026	2.75	-10.24
2	3.026	2.50	-7.74
3	3.026	2.27	-5.47
4	3.026	2.07	-3.4
5	3.026	1.88	-1.52
6	3.026	1.71	0.19
7	3.026	1.55	1.74
8	3.026	1.41	3.15
9	3.026	1.28	4.43
10	3.026	1.17	5.6

#### 4.5. Internal Rate of Return (IRR) Analysis

IRR solves for the interest rate that equates the equivalent worth of an alternative's cash inflows to the equivalent worth of cash outflows. Using present worth method, the Internal Rate of Return for this project is determined as follows.

$$PW = 0$$

$$0 = -RM\ 12.99\ \text{mil} + RM\ 3.026\ \text{mil} (P/A, i\%, 10)$$

By interpolation  $\Rightarrow PW = 0$ , at  $i = 19.3\%$

Present worth is drawn against interest rate in Figure 5. The internal rate of return is greater than the MARR that has been set by the organization (10%). Thus, this project is economically justified.

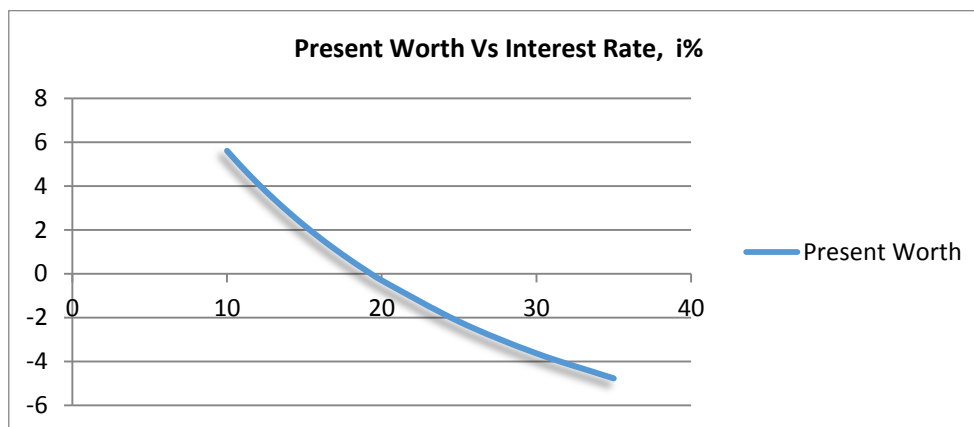


Figure 5: Graph of PW vs Interest Rate

#### 4.6. Sensitivity Analysis

The sensitivity analysis is done using spider plot as illustrated in Figure 6. The sensitivity of project is evaluated between -40 % and + 40 % for the net revenue gain, capital investment, salvage value and operating cost.

From Interest & Annuity Table:  $(P/A, 10\%, 10) = 6.1446$

*PW @ 10% (RM Mil) - Changing "Capital Investment"*

$$PW(10\%) = -RM\ 13\ \text{mil} \cdot [1 \pm P\%/100\%] + RM\ 0.0048\ \text{mil} + RM\ 4.94\ \text{mil} (P/A, 10\%, 10)$$

$$= -RM\ 1.914\ \text{mil} (P/A, 10\%, 10)$$

$$= -RM\ 13\ \text{mil} \cdot [1 \pm P\%/100\%] + RM\ 0.0048\ \text{mil} + RM\ 3.026\ \text{mil} (P/A, 10\%, 10)$$

*PW @ 10% (RM Mil) - Changing "Net Revenue Gain"*

$$PW(10\%) = -RM\ 13\ \text{mil} + RM\ 0.0048\ \text{mil} + RM\ 4.94\ \text{mil} (P/A, 10\%, 10) \cdot [1 \pm P\%/100\%]$$

$$= -RM\ 1.914\ \text{mil} (P/A, 10\%, 10)$$

*PW @ 10% (RM Mil) - Changing "Salvage Value"*

$$PW(10\%) = -RM\ 13\ \text{mil} + RM\ 0.0048\ \text{mil} \cdot [1 \pm P\%/100\%] + RM\ 4.94\ \text{mil} (P/A, 10\%, 10)$$

$$= -RM\ 1.914\ \text{mil} (P/A, 10\%, 10)$$

$$= -RM\ 13\ \text{mil} + RM\ 0.0048\ \text{mil} \cdot [1 \pm P\%/100\%] + RM\ 3.026\ \text{mil} (P/A, 10\%, 10)$$

*PW @ 10% (RM Mil) - Changing "Annual Cost"*

$$PW(10\%) = -RM\ 13\ \text{mil} + RM\ 0.0048\ \text{mil} + RM\ 4.94\ \text{mil} (P/A, 10\%, 10) - RM\ 1.914\ \text{mil}$$



$$(P/A, 10\%, 10) \cdot [1 \pm P\%/100\%]$$

The sensitivity graph shown in Figure 6 reveals the sensitivity of the Present Worth of the proposal to percentage changes in respective factors' best estimate. The relative degree of sensitivity of the Present Worth to each factor is indicated by the gradient of the curves (the steeper the curve, the more sensitive the present worth is to the factor). It is apparent that the present worth is highly sensitive to the variation of the NRG (Net Revenue Gain) of chilled water production. On the contrary the present worth is not sensitive to changes in SV (Salvage Value), CI (Capital Investment) and AC (Annual Cost).

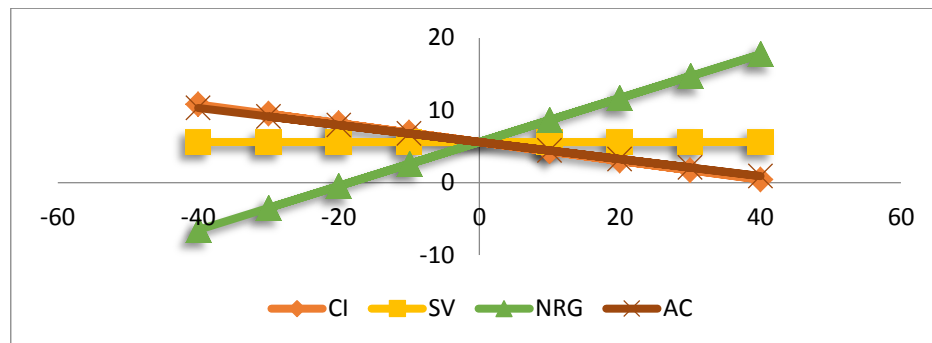


Figure 6: Sensitivity Graph

## 5. DISCUSSION

The economic analysis undertaken in this study showed the justification to replace two existing units of SACs. Hence it is concluded from this analysis that proposed replacement is financially viable and economically acceptable. Furthermore, it is determined that the investment will be paid back at the end of the sixth year and the proposed replacement will generate acceptable return of return of 19% per year.

## 6. CONCLUSION

The engineering economic analyses provided positive justification to the proposed replacement of the existing two units of absorption chillers (Unit A & B) with two new units of absorption chiller. The proposed investment is justified by a positive present worth and six years of discounted payback period. Furthermore, internal rate of return is calculated to be higher than regulated MARR that further increases the acceptability of project under consideration.

Moreover, the sensitivity of project under consideration is determined for several important factors like capital investment, net revenue gain, operational cost and salvage value and from the findings it is concluded that the proposed investment is highly sensitive to variation in net revenue gain. Hence, due focus must be given to the variation of the yearly net revenue gain in order to ensure the continuous feasibility of the investment through-out its life cycle. The proposed replacement will enhance plant's overall performance by increasing production of chilled water to meet future demands.

Hence it is concluded from above results that the proposed investment will not only cater future load demands of customer but also provides a sound increment in revenue and cost savings. However, other non-monetary factors such as Health, Safety and Environment (HSE) aspects of the investment should also be given due consideration in the final decision by the management.

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