Refrigerant Management By Using IoT Technology And Co-Benefit In Energy Saving At Malaysia Food Base Sector

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1. Introduction

Refrigeration system is widely used in commercial and industry sector, where fluorocarbon (FC) gas has been utilized as a cooling agent (Mylona et al., 2017). Where each of the FC gas contains ozone depletion potential (ODP) and global warming potential (GWP), that can contribute in direct and indirect impact to the environment due to FC gas leakage and increase in electricity consumption (Park et al., 2021). Whereas, shortage of FC gas will decrease in cooling capacity, extended the operating time to meet the cooling load. Sensor device as one of the main components of Internet of Thing (IoT) (Ejaz et al., 2017) and popular in condition monitoring to optimized maintenance of mechanical and electrical system. This is due to their ability to capture the data from the inside of the system and transfer it to the server for monitoring of real-time energy consumption (Tan et al., 2017). Therefore, this study will be involved ultrasonic sensor detection system to detect from 10% of refrigerant leakage that appears in the liquid line. So, the aim of this study is to determine the scenario of refrigerant leakage management and the reduction potential of electricity cost together with carbon and GHG emission by refrigerant leak reduction in food industry sector in Malaysia

2. Methodology

This study is conducted at food manufacturing (Facility A) and commercial facility (Facility B) in Malaysia. This project is involved in the installation of early fluorocarbon (FC) gas leakage detection device on a chiller unit at Facility A and B. The data was monitored in three phases which is the actual scenario of refrigerant leakage, after countermeasure and final monitoring. Besides, the history data collection of electricity price and maintenance report of the fluorocarbon gas had been collected from each facility to calculate potential electricity consumption and reduction of direct and indirect emission. The estimation of energy saving, electricity consumption, and total of direct and indirect emission has been calculated by using (1) - (4) formulas (refer appendix) which adopted from The Japan Refrigeration and Air Conditioning Industry Association (JRAIA),

Equation of reduction of direct emission as follow:

$$\text{Total direct} = \frac{\text{No. of cylinder of fluorocarbon gas (mass of fluorocarbon gas (kg))}}{1000} \times \text{GWP} \quad (1)$$

where GWP value for R-22 is 1810 while R-507 is 3985

Reduction of indirect emission can be calculated by using this equation:

$$\text{Total indirect emission} = \frac{\text{Electricity consumption (kWh)}}{1000\text{ M}} \times \text{grid emission factor } (tCO_2/\text{MkWh}) \quad (2)$$

where grid emission factor, 0.694 tCO_2 /MWh, obtained from Tenaga Nasional.

Actual reduction of energy saving will be estimate by using following equation:

$$\text{Energy Saving} = \left[\text{Average electricity consumption before early detection (kWh)} - \text{Average electricity consumption after early detection (kWh)} \right] \text{365 days} \quad (2)$$

where average electricity consumption before early detection is daily electricity consumption during Phase 1; Average electricity consumption after early detection is daily electricity consumption during Phase 2 (after counter measure)

Average amount of electricity saving can be estimate by using following equation:

$$\text{Average amount of electricity savings} = \frac{\text{Average Electricity consumption before early detection(kWh)}}{\text{Average operation (\%)}} \times \text{Ideal rate of operation (\%)} \quad (3)$$

The following equation is using to estimate energy saving of reduction potential:

$$\text{Electricity consumption under normal condition} = \left[\text{Average Electricity consumption before early detection(kWh)} \times \text{Average amount of electricity savings (kWh)} \right] \text{365 days} \quad (4)$$

where average operation is operating rate during Phase 1

3. Result and discussion

3.1 Facility A

The Facility A show as early as week one of response time to mitigate the 33.9% of FC gas leakage during phase 1 (refer Table 3.1), by recharge 16.3 kg of hydrochlorofluorocarbon-22 (HCFC-22). The leakage rate significantly reduced to 0.7%, but the electricity consumption has been increased in Phase 2 due to the shortage of refrigeration capacity. Reoccurrence of FC gas leakage (1.9%) was occurring in Phase 3. From this scenario, Table 3.2 shows the reduction potential of the freezer room during the normal operation. The simulation of the actual reduction cannot be calculated due to an increase in electricity consumption after fluorocarbon gas recharge during Phase 2. The result show amount of greenhouse gas (GHG) and carbon emission (CO2) can be reduced by 30 t-CO2e/yr and 13t-CO2/yr. At the same time, co-benefit in the reduction of electricity consumption cost can be saved up to 9,400 RM/yr which approximately 19,000 kWh/yr of energy saving can be achieved.

Table 3.1. Summary of scenario of fluorocarbon gas leakage for Facility A and Facility B.

Facility	Facility A		Facility B	
	Leakage of FC gas	Electricity consumption	Leakage of FC gas	Electricity consumption
Phase 1	33.9%	112.3 kWh	60.6%	1151.4 kWh
Phase 2	0.7%	137.7 kWh	27.0%	1072.7 kWh
Phase 3	1.9%	137.7 kWh	43.1%	1307.5 kWh

3.2 Facility B

The Facility B show 60.6% of FC gas leakage in Phase 1 as shown in Table 3.1. As early as week six, 45 Kg of hydrofluorocarbon-507A (HFC-507A) has been recharge and FC gas leakage has reduced to 27% in Phase 2. In Phase 3, 43.1% reoccurrence of FC gas leakage has occurred and increased the electricity consumption. Based on Table 3.2, Facility B successful reducing 180 t-CO2e/yr of GHG emission from the leakage of fluorocarbon gas. In addition, with 29,000 kWh/yr of reduction which equivalent to the 10,000 RM/yr of electricity consumption, has reduced 20 t-CO2/yr of CO2 emission. Besides that, under normal operation, the reduction potential has been estimated to reduced 460 t-CO2e/yr of GHG emission. In addition, estimated 90 t-CO2/yr of carbon emission potentially can be reduced as 136,000 kWh/yr of energy saving can be achieved which approximately cost of electricity consumption can be saved up to 49,000 RM/yr.

Table 3.2. Summary of reduction potential for Facility A and Facility B.

Facility		Facility A	Facility B
Actual reduction	Direct emission	-	180 t-CO_2e/yr
	Indirect emission	-	20 t-CO_2e/yr
	Energy saving	-	29 000 kWh/yr
Reduction potential	Direct emission	30 t-CO_2e/yr	460 t-CO_2e/yr
	Indirect emission	13 t-CO_2e/yr	90 t-CO_2e/yr
	Energy saving	1 500 kWh/yr	136 000 kWh/yr

4. Conclusion

As a conclusion, the scenario of fluorocarbon gas leakage at Facility A and Facility B is different in terms of response rate, fluorocarbon gas leakage and specific optimum operation condition. At the same time, each facility can achieve huge reduction potential on carbon and GHG emission also co-benefit in energy saving when the refrigeration equipment is functioning in optimum condition.

5. Reference

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