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Comparison of Liquefied Natural Gas Plant Unit Failure

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Abstract

The comparison of some liquefied natural gas plant unit failure was investigated and the unit considered in terms of identification of the component failures. The units are Reboiler, Stripper, Cooling, Compressor, Acid Dehydration, Heat Transfer, Expander and Liquefaction units. The components of interest were monitored in terms of their performance as well as the failure rate of heat transfer unit > cooling unit > acid dehydration unit > stripper unit $\geq$ expander unit > reboiler unit $\geq$ liquefraction unit > compressor unit as the period of investigation. The investigation revealed the effect of operational conditions on the failure rate of each unit plant of the Liquefied Natural Gas plant.

Keywords: Comparison, liquefied, natural, gas, plant, unit, failure

INTRODUCTION

Identification of components failure has been found useful as the research work outlines the significance and importance of the process to risk reduction, increase in profit making as well as optimum production [1]. It provides the required need for optimum performance of the industrial operation with less friction in the model of operation. However, the significance of reliability analysis in a process plant contributes to good maintainability, productivity, services time increase of the process plant unit, less risk analysis, less accident occurrence, improvement in the economic value of the plant, management policy in terms of maintainability of plant to improve reliability etc [2]. The asset reliability process of the Nigerian Liquefied Natural Gas Plant Programme (NLNGPP) is identified as a major contributor to NLNG unit components failure [3]. In this case, it is observed that the management of physical asset performance is the major concept to business success [4]. A good business maintainability yield results in terms of maintenance of physical asset reliability [5-9]. For an effective performance, a proactive asset reliability technique is necessary such as plant improvement and control model concept necessary for effective delivery of the performance of the plant units for optimum production and profit making [10-11].

However, to reduce failure in NLNG plant the following components are recognized as contributing factors, such as work identification, planning, scheduling, execution, follow-up and performance analysis on unit section monitory in terms component performance [12-14]. The aim of this study is to carryout comparison of reliability analysis of some units of a liquefied natural gas plant. The specific objectives of this research are to: Examine the causes of leakage in NLNG plant, identify the component failures in each unit: Reboiler, Stripper, Cooling, Compressor, Acid Dehydration, Heat Transfer, Expander and Liquefaction units, determine reliability and unreliability

The study of the liquefied natural gas (LNG) reliability analysis was established by using the following approach, such as analysis of the root cause of the failure, from NLNG based on occurrence of failure and application of reliability tools and techniques to analyze the data obtained into mathematical language

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Various problems have been identified to be associated with leakage in liquefied natural gas process plant in terms of low profit making, increase in operational risk, high maintainability, cost of unreliability. The design factors, construction error, utilization process and maintenance culture and others are identified as problems that contribute to liquefied natural gas plant failure. This research work shall provide the necessary reliability tools and techniques which can be used to achieve good improvement in reducing leakages in essential component of the plant.

The developed models will be geared towards enhancing improvement on the NLNG plant that is the constrain that leads to leakages will be highlighted, the failure rate. Models developed will be useful in predicting the effect of leakage on NLNG plant upon the influence of root cause analysis. The success of this research work will address most of the inadequate in solving problems in reliability engineering. Due to the frequent failure of LNG plant upon the influence of aging or over utilization, there is need to look at the leakage problems that may arise.

MATERIALS AND METHODS

Reliability

The reason why engineering management actions is found necessary in process plant reliability is because of its significant impact on process reliability, unreliability, profitability, availability and maintainability [6]. The research work focus on the understanding of the human characteristics on plant risk and the safety involvement as well as mathematical model was developed on the concept of influence of human characteristics in terms of behaviour in risk and safety management.

The study on the process reliability framework was based on two concepts of managing human behaviour on plant operation as well as the engineering application was considered. The operator process performance and other constraints were evaluated in their research work such as operations of processing equipment in terms of failure condition. Lack of trained manpower used in the plant, lack of required experience to manage the plant for effective operation and maintainability, lack of adequate control measure to identify fault for effective control action is lacking in some plant. The significant of reliability can be attributed to the engineering management of the process plants. Mathematical approach was used in explaining the concepts involved in analysis of management actions due to failure of a process plant caused by human behaviour. In this case, data are generated and gathered as a result of various failures experienced in the operation of the plant [1].

The studies on the hierarchical levels of system interactions on the industrial operational steps were investigated in terms of the concepts of the significant of engineering management system (EMS), system operation (SO), physical system (PS) as well as the contribution of these functional parameters to the failure state of the system. It was observed that engineering management system, physical system and system operation influence directly the analysis of the failure state (FS) experienced in system [4].

The investigation carried out revealed the accident probability estimation model [4] as described below:

$$P_A = \sum_a \sum_b \sum_c \sum_t P_A\,(a,b,c,t)^A \; P_A\,(Accident|\,a,b,c,t) \tag{1}$$

Where P (a, b, c, t) represent the probability of the event involving stages in 9the concept with the EMS) b (the concept of system operation SO), c (the concept of physical system PS-E) and the t (concept of PS-SS), P_A (Accident |a, b, c, t) is the accidental probability in the concepts of conditional scenario in terms of a,b,c and t. The model was further expressed as:

$$P_A\,|a,b,c,t = \int_{-\alpha}^{\alpha} fabct(z)\,Pabct(z)dz \tag{2}$$

$$f_{abct}(z) = (\frac{2}{m^2})z + \frac{2}{m} \tag{3}$$

$$P_{abct}(z) = \beta_1 e^{\beta 2z} \tag{4}$$

Where fabct is task – distribution demand, m is related to proportional operation system β_1 and β_2 represent linear impact attributed to ability and exponential impact respectively. The impacts of the various scenarios were formulated for the engineering management system (EMS), system operation (SO), physical system equipment (PSE) and physical system safety, system (PS-SS). Thus:

$$Im\,a\,ct_{QLE} = \frac{P_{QLE}}{P_{QLE}+P_{SLE}+P_{WLE}} \tag{5}$$

$$Im\,a\,ct_{SLE} = \frac{P_{SLE}}{P_{QLE}+P_{SLE}+P_{WLE}} \tag{6}$$

$$Im\,a\,ct_{WLE} = \frac{P_{WLE}}{P_{QLE}+P_{SLE}+P_{WLE}} \tag{7}$$

Where S_{LE} represent the engineering and management team emphasis on low training of workers in terms of safety

Q_{LE} represent the engineering and management team emphasis on low training of workers in terms of improvement.

W_{LE} represent the engineering and management team emphasis on high training of workers in terms of improvement

P_{QLE} represent the probability of engineering and management team emphasis on low training of workers in terms of improvement

P_{WLE} represent the probability of engineering and management team emphasis on high training workers in terms of improvement.

P_{SLE} represent the probability of engineering and management team emphasis on low training workers in terms of safety.

Products Plant of Life Cycle and Cost Analysis

Plant life cycle unreliability cost was analyzed using mathematical approach on the assessment and comparison of the plant process. In their investigation modeling system was applied the case of quantifying the cost element that are necessaries in the development of the process. Correlative model was developed to examine the functional parameters of cost effective elements that control the system. Mathematical model was developed to monitor the availability and the maintainability as well as the significant of the developed model to life cycle cost analysis of process plant. The significant of the availability in terms of production facilities and their effect on cost of unreliability was well explained in their studies. The model prediction in terms of availability as well as the repairable cost of unreliability as it involves the expression stated below:

$$A^1 = \frac{M^1{}_{TTF}}{M^1{}_{TTF}+M^1{}_{TTR}} \tag{8}$$

$$A^1 = \frac{M^1{}_{TTE}}{M^1{}_{TBF}} \tag{9}$$

Where A^1 represent availability
M^1_{TTF} represent mean time to failure
M^1_{TBF} represent mean time between failures
M^1_{TFR} represent mean time to repair
The mathematical model for the system in terms of availability is showcased on the Figure 1.

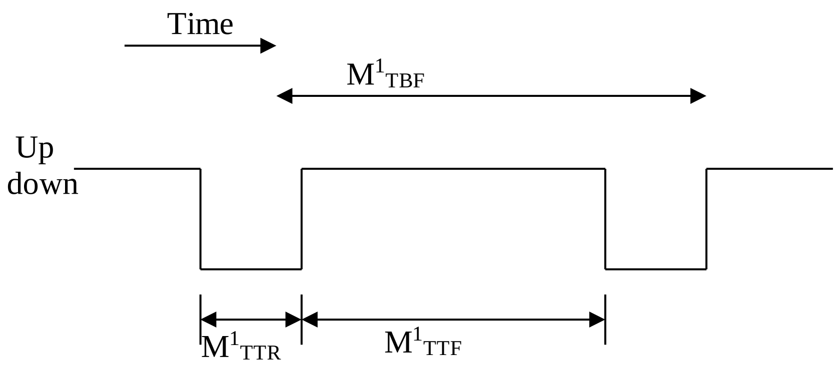

Figure 1. Illustrates the region classified as M1TTR, M1TTF and M1TBF

Therefore,

$$A^1{}_1 = \frac{M^1{}_{TBF}}{M^1{}_{TBF} + M^1{}_{CT}} \tag{10}$$

$$A^1{}_2 = \frac{M^1{}_{TBF}}{M^1{}_{TBM} + M^1{}_{AV}} \tag{11}$$

$$A^1{}_3 = \frac{M^1{}_{TBM}}{M^1{}_{TBM} + M^1{}_{DT}} \tag{12}$$

Where, M^1_{CT} represent mean corrective maintenance time
M^1_{TBM} represent mean time between maintenance time
M^1_{AV} represent mean active maintenance time
M^1_{TT} is parameters of time functions (flow time, maintenance time, time delay, logistic time
A^1_1, A^1_2, $A^1_3$is parameters of availability functions (inherent, achieved and operational)

In the cost of unreliability a discount was obtained which was analyzed using the life cycle cost analysis and the mathematical expression applied is as stated below

$$(NPV)^1 = \sum_{n=o}^{T} C_m (1+x)^{-q} \tag{13}$$

X is represented by discount rate and T is time period
Q is period of costing in terms of life cycle (specific year)
Cm is cash flow and $(PVO)^1{}_w$future net value

Considering when there is change in price leading to increase in the cost unreliability on the operation of the process plant.

$$(ET)^1 = (1 + E_1)(1 + E^1{}_2)(1 + E^1{}_3)\ldots\ldots(1 + E^1{}_2) \tag{14}$$

Where, $(ET)^1$ is represented by change in price that influence rate cost of unreliability

E^1 is represented by influence rate in i^{-th} year

Sampling

Table 1 demonstrates the data sampling which was translated to mathematical language and other computational procedures were applied for the evaluation of the functional parameters

RESULTS AND DISCUSSION

The result demonstrated in this investigation showcases the comparison in terms of Figures and Tables. Table 2 showcases the translation of the failures into values whereas Table 3 was related to the determination of some functional parameters. Table 4 demonstrates the reliability and unreliability check in terms of percentage effect in each unit plant.

Table 1. Data collection on number of failures of each plant unit for the period of investigation.

	Failure per Year – 1st May 2011 to 1st May 2018								
Parameters	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*Total Number of Failure*
Reboiler unit		X						X	2
Stripper unit			X		X	X			3
Cooling unit		X		X			X		3
Compressor unit	X								1
Acid dehydration unit		X		X	X	X			4
Fluid unit	XX		X	X	X		X		6
Expander unit			X			XX			3
Liquefaction unit	X				X				2

where X represent yearly unit failure

Table 2. Computation values of some of the functional parameter for various unit plant.

Components	**Reboiler unit**	**Stripper unit**	**Cooling unit**	**Compressor unit**	**Acid dehydration unit**	**Heat transfer unit**	**Expander unit**	**Liquidation unit**
Gross margin	160	360	500	100	416	2160	324	200
Scrap disposal cost per incident	16	24	40	8	32	48	24	16
Breakdown maintenance cost ($)	32	72	200	8	128	288	72	32

Table 3. Computation values of some of the functional parameter for various unit plant.

Components	**Reboiler unit**	**Stripper unit**	**Cooling unit**	**Compressor unit**	**Acid dehydration unit**	**Heat transfer unit**	**Expander unit**	**Liquiefaction unit**
Failure rate	4.57×10^{-5}	6.00×10^{-5}	1.14×10^{-4}	228×10^{-5}	7.13×10^{-5}	1.30×10^{-4}	6.85×10^{-5}	4.57×10^{-5}
Failure per year	0.400	0.600	0.999	0.1997	0.7998	1.200	0.600	0.400
Corrective time failure	2	3	5	1	7	6	3	2
Lost time per failure	0.80	1.80	4.995	0.1997	3.1992	7.2	1.800	0.8

Table 4. Reliability and Unreliability check for various units.

Time years	**Reboiler units**		**Stripper unit**		**Cooling units**		**Compressor unit**		**Acid dehydrated unit**		**Heat transfer fluid units**		**Expander unit**		**Liquefaction unit**	
	Reliability R_{Reb} *(%)*	*Unreliability* U_{Reb} *(%)*	*Reliability* R_{Str} *(%)*	*Unreliability* U_{Str} *(%)*	*Reliability* R_{Coo} *(%)*	*Unreliability* U_{Coo} *(%)*	*Reliability* R_{Com} *(%)*	*Unreliability* U_{Com} *(%)*	*Reliability* R_{Aci} *(%)*	*Unreliability* U_{Aci} *(%)*	*Reliability* R_{Hea} *(%)*	*Unreliability* U_{Hea}*(%)*	*Reliability* R_{Exp} *(%)*	*Unreliability* U_{Exp} *(%)*	*Reliability* R_{Liq}*(%)*	*Unreliability* U_{Liq} *(%)*
1	67.03	3897	54.85	45.15	36.84	63.16	81.90	18.10	44.94	55.06	30.12	69.88	54.88	45.12	67.03	38.97
2	44,90	55.10	30.12	69.88	81.90	18.10	67.07	32.93	20.20	79.80	9.07	90.93	30.12	69.88	44.90	55.10
3	30.09	69.91	16.53	83.47	5.0	95.00	34.93	45.07	9.10	90.90	2.73	97.27	16.52	83.48	30.09	69.91
4	20.16	79.84	9.07	90.93	1.84	98.20	44.98	55.02	4.08	95.92	0.82	99.18	9.07	90.93	20.16	79.84
5	13.51	86.49	4.96	95.04	0.68	99.32	33.25	66.75	1.83	98.17	0.25	99.75	5.00	95.00	13.57	86.49
6	9.05	90.95	2.73	97.27	0.25	99.75	30.17	69.83	0.82	99.18	0.075	99.93	2.73	97.27	9.05	90.95
7	6.07	93.93	1.50	98.50	0.092	99.91	24.71	75.29	0.37	99.63	0.022	99.98	1.50	98.50	6.07	93.93
8	4.07	95.94	0.82	99.18	0.034	99.97	20.23	79.77	0.17	99.83	0.007	99.99	0.82	99.18	4.07	95.44

Failure Rate of Units of Plant

The result of Failure Rate against unit of plant was examined as presented in Figure 2.

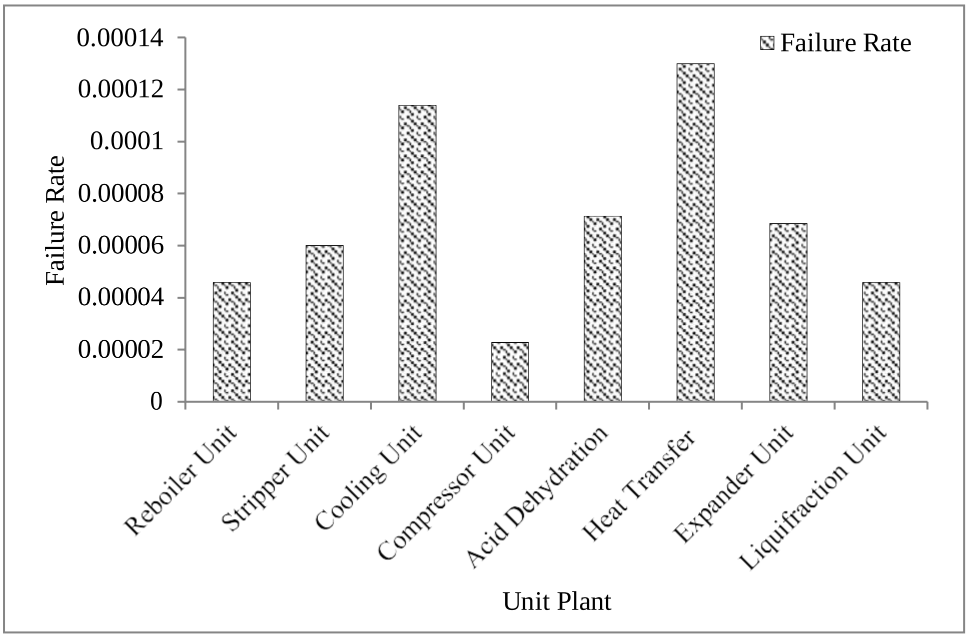

Figure 2. Graph of failure rate versus unit of plant.

Figure 2 illustrates the failure rate of each unit plant as described for reboiler, stripper, cooling, compressor, acid dehydration, heat transfer, expander and liquefraction unit. The order of magnitude in terms of failure rate is given as heat transfer unit > cooling unit > acid dehydration unit > stripper unit ≥ expander unit > reboiler unit ≥ liquefraction unit > compressor unit.

Failure per Year of Units of Plant

The result of Failure per year against unit of plant was examined as presented in Figure 3.

Figure 3 illustrates the failure per year of the various unit sampled in the liquefied natural gas plant. The results obtained revealed the order of magnitude of the failure per year as heat transfer unit > cooling unit > acid dehydration unit > stripper unit ≥ expander unit > reboiler unit ≥ liquefraction unit > compressor unit. The variation on failure per year of each unit can be attributed to operating condition and the culture of maintainability in terms of repair and other contributing factors.

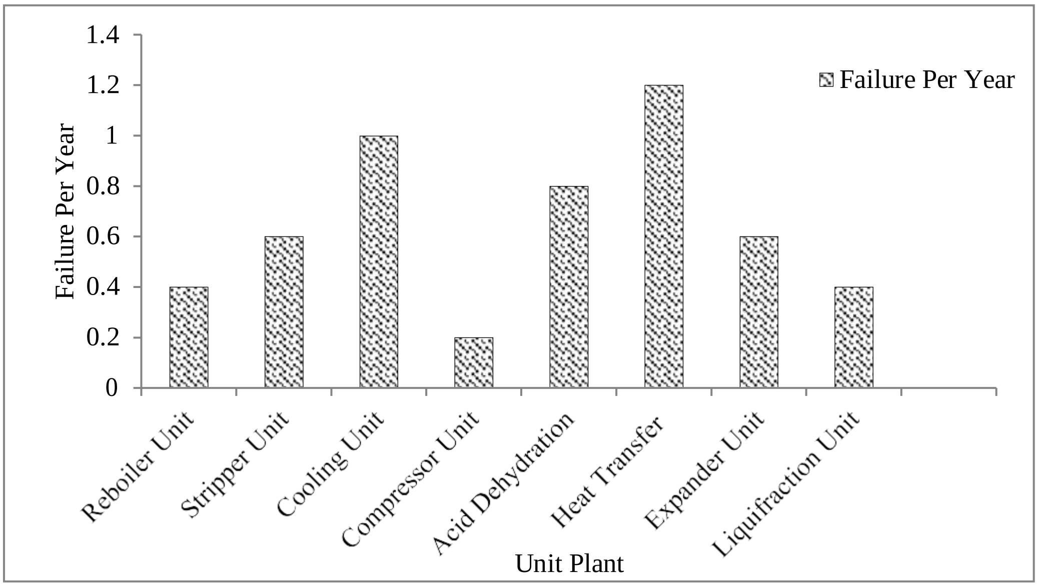

Figure 3. Graph of failure per year versus unit plant.

Corrective Time Failure of Units of Plant

The result of Corrective time failure against unit of plant was examined as presented in Figure 4.

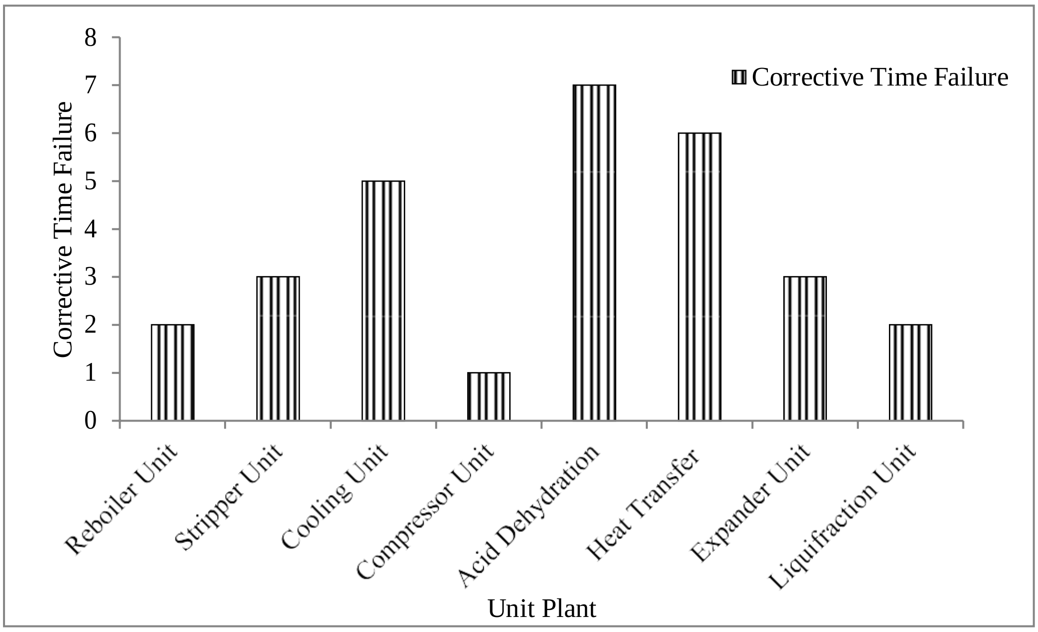

Figure 4. Graph of corrective time failure versus unit plant

Figure 4 demonstrates the corrective time failure of each plant unit investigated for this research work. The results obtained revealed the order of magnitude in terms of the corrective time failure of the liquefied natural gas plant component units as acid dehydration unit > heat transfer unit > cooling unit > stripper unit ≥ expander unit > reboiler unit ≥ liquefraction unit > compressor unit.

Lost Time per Failure of Units of Plant

The result of lost time per failure against unit of plant was examined as presented in Figure 5.

Figure 5 illustrates the lost time per failure for the various plant units studies. The result obtained reveals that the order of magnitude in terms of lost time per failure is heat transfer unit > cooling unit

> acid dehydration unit > stripper unit ≥ expander unit > reboiler unit ≥ liquefraciton unit > compressor unit. The variation in lost time per failure of each unit can be attributed to the operational conditions.

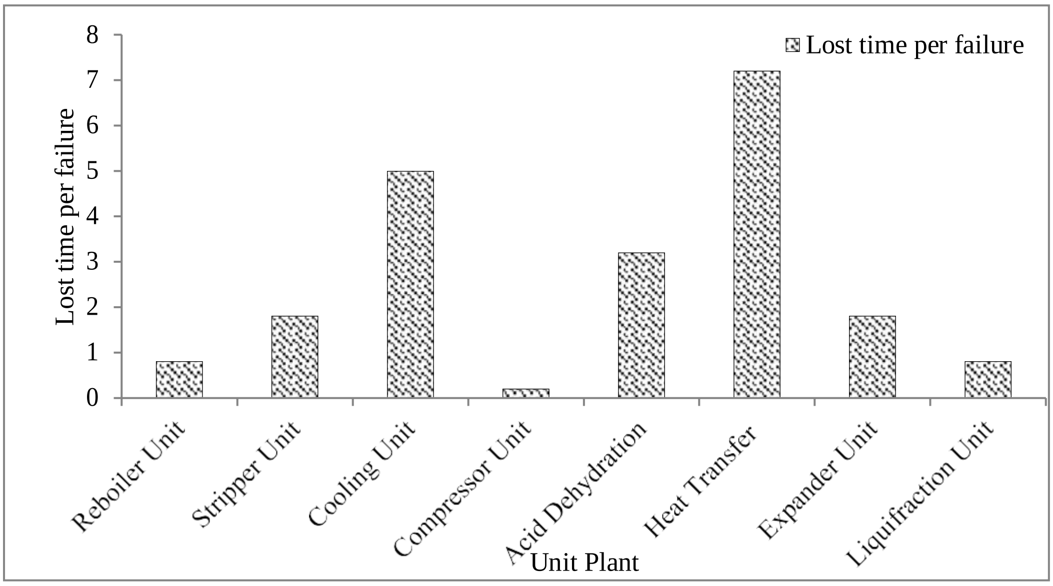

Figure 5. Plot of function of failure per time versus components

Gross Margin of Units of Plant

The result of Gross Margin against unit of plant was examined as presented in Figure 6.

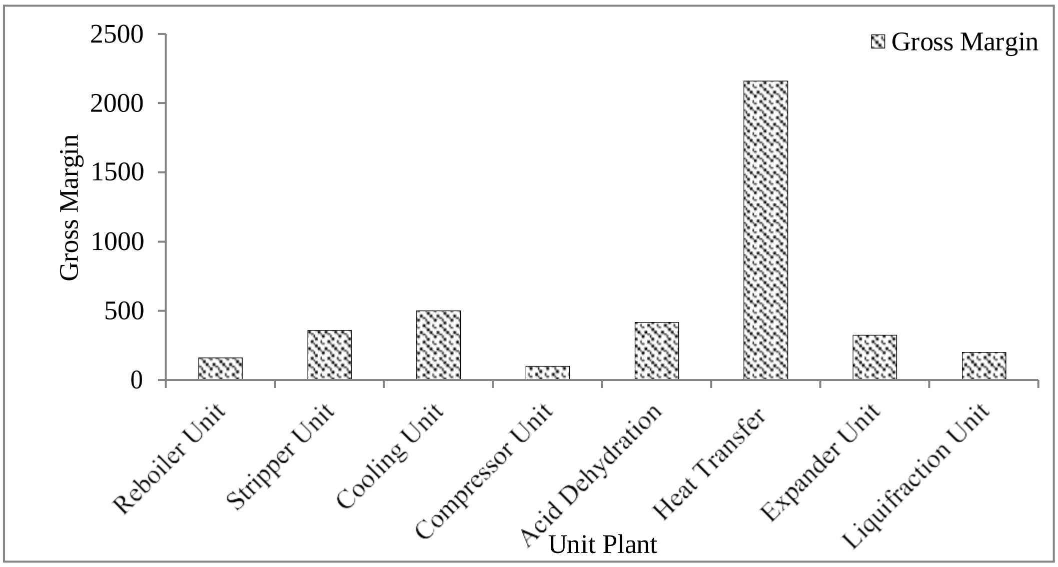

Figure 6. Graph of gross margin versus unit plant

Figure 6 demonstrates the reliability model of LNG unit plant and the results obtained revealed the order of magnitude as stated compressor unit > reboiler unit ≥ liquefraciton unit > expander unit ≥ stripper unit > acid dehydration unit > cooling unit > heat transfer unit. In this case, the reliability was based on the performance of each unit before failure of the unit components.

Cost on Scrap Disposal

The result of Scrap Disposal Cost per incident against unit of plant was examined as presented in Figure 7.

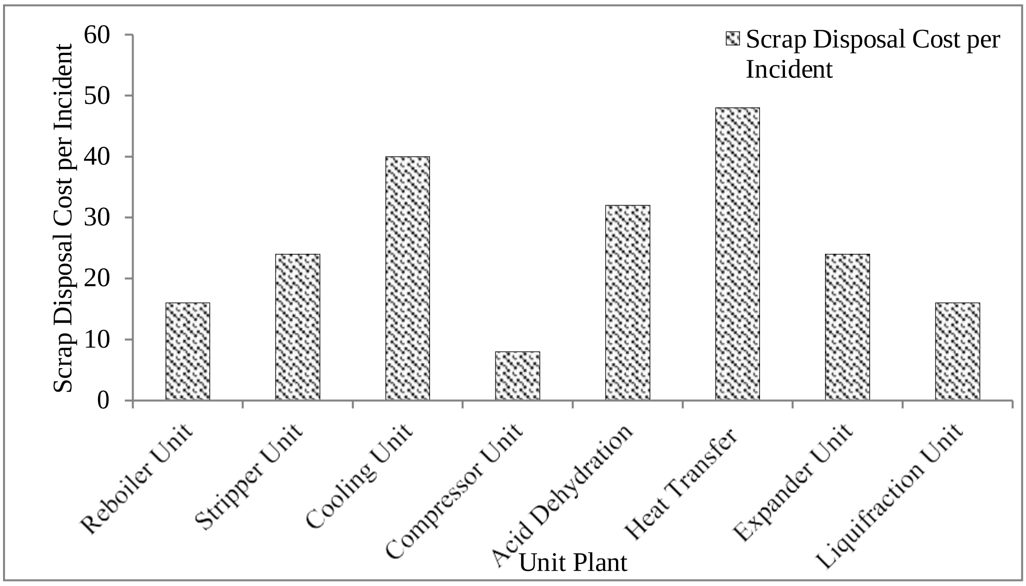

Figure 7. Graph of scrap disposal cost per incident

From Figure 7 it is seen that the unreliability of the unit plant for the liquefied natural gas plant investigated in terms of unreliability. Results obtained revealed the order of magnitude of the process plant unit as stated, heat transfer unit > cooling unit > acid dehydration unit > stripper unit ≥ expander unit > reboiler unit ≥ liquefraction unit > compressor unit. The cost of unreliability is due to low performance and high maintainability cost of the various unit obtain in the period under investigation.

Breakdown Maintenance Cost

Figure 8 predicted the breakdown cost of maintenance of each component investigated in the Liquefied Natural Gas Plant Unit.

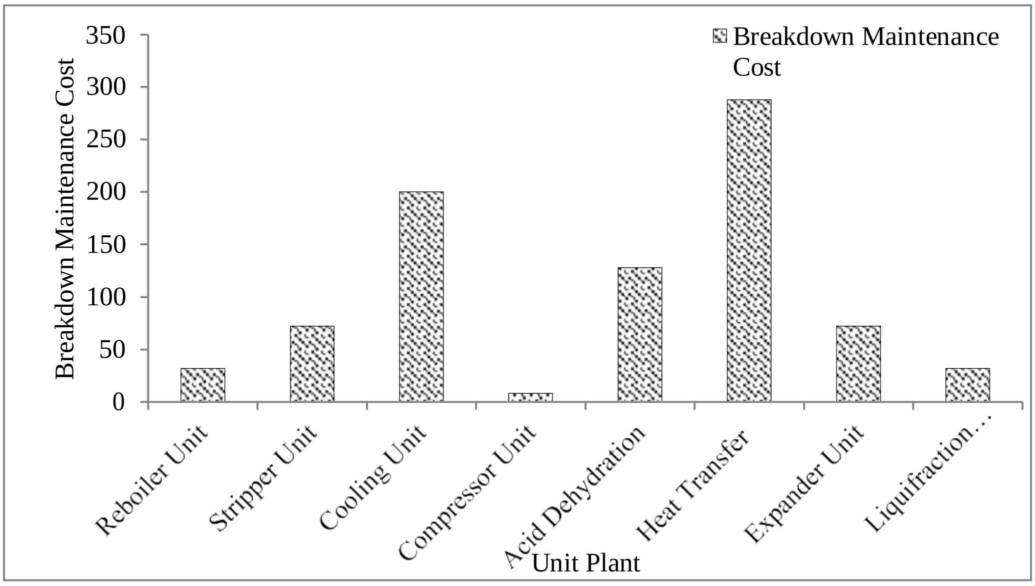

Figure 8. Graph of breakdown maintenance cost

Figure 8 demonstrates the relationship between availability of component parts for each unit of the liquefied natural gas plant. The results obtained revealed the availability of each unit component parts in the order of magnitude as stated, stripper unit ≥ compressor unit reboiler unit ≥ cooling unit > expander unit ≥ liquefraction unit > acid dehydration unit > heat transfer unit.

Reliability Model LNG (%) of Units of Plant

The result of Reliability Model LNG (%) was examined as presented in Figure 9.

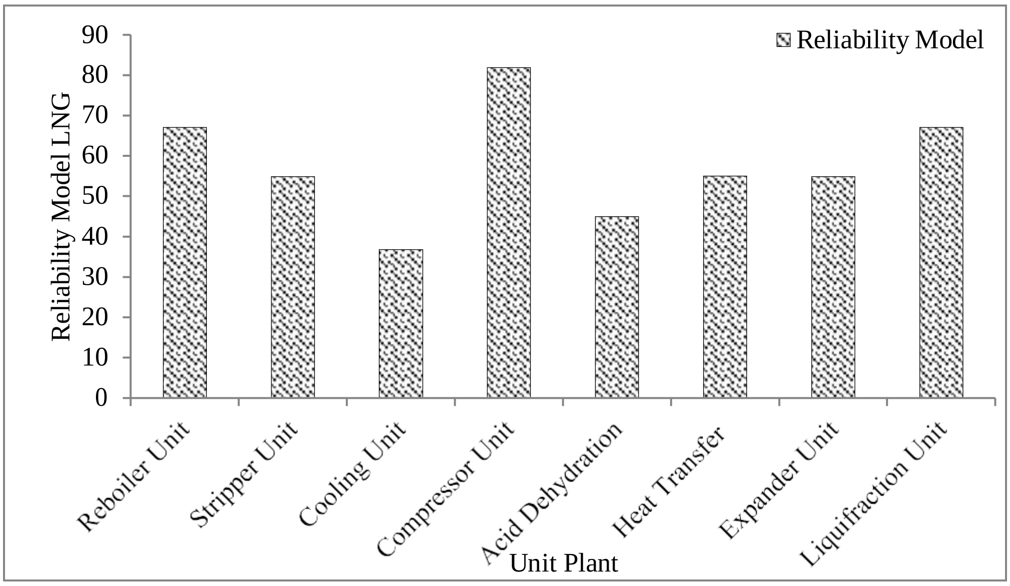

Figure 9. Graph of reliability model LNG (%) versus unit plant

Figure 9 demonstrates the gross margin of each unit plant upon the period of exposure and operational conditions. The result shows that the gross margin cost order of magnitudes is heat transfer unit > cooling unit > stripper unit > expander > liquefraction unit > reboiler unit > compressor unit. The variation in the gross margin cost can be attributed to the variation in the number of failure of each unit components.

Unreliability Model LNG (%) of Units of Plant

The result of Unreliability Model LNG (%) was examined as presented in Figure 10.

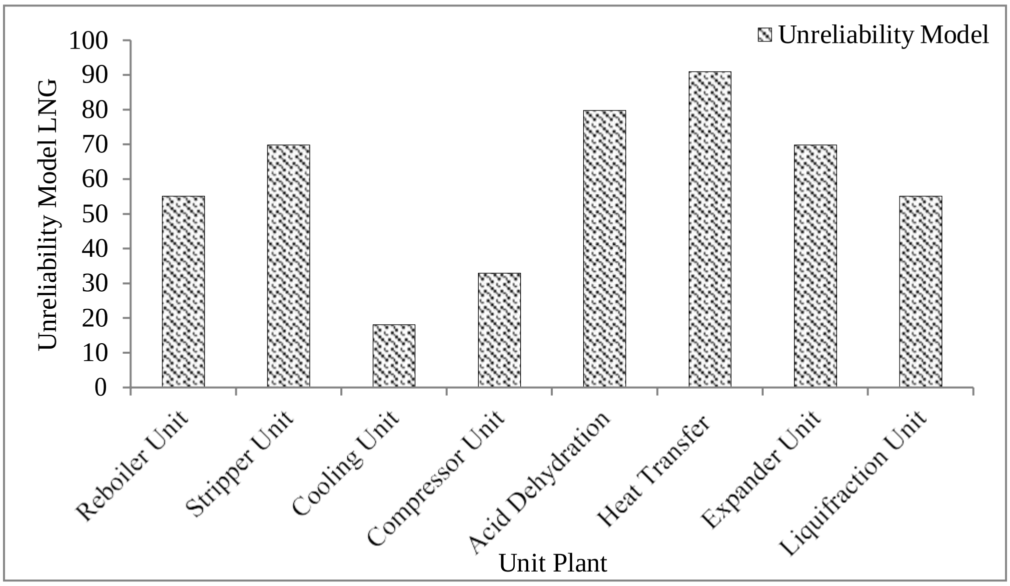

Figure 10. Graph of unreliability model LNG (%) versus unit plant

From Figure 10 it is seen that scrap disposal per incident was examined with unit plant failures. The results obtained revealed the order of magnitude as described heat transfer unit > cooling unit > acid dehydration unit > expander unit ≥ stripper unit > reboiler unit ≥ liquefraction unit > compressor unit. The variation in the scrap disposal cost per incident can be attributed to variation in number of failures of each unit component.

Availability Model LNG (%)

The result of Availability Model LNG (%) was examined as presented in Figure 11.

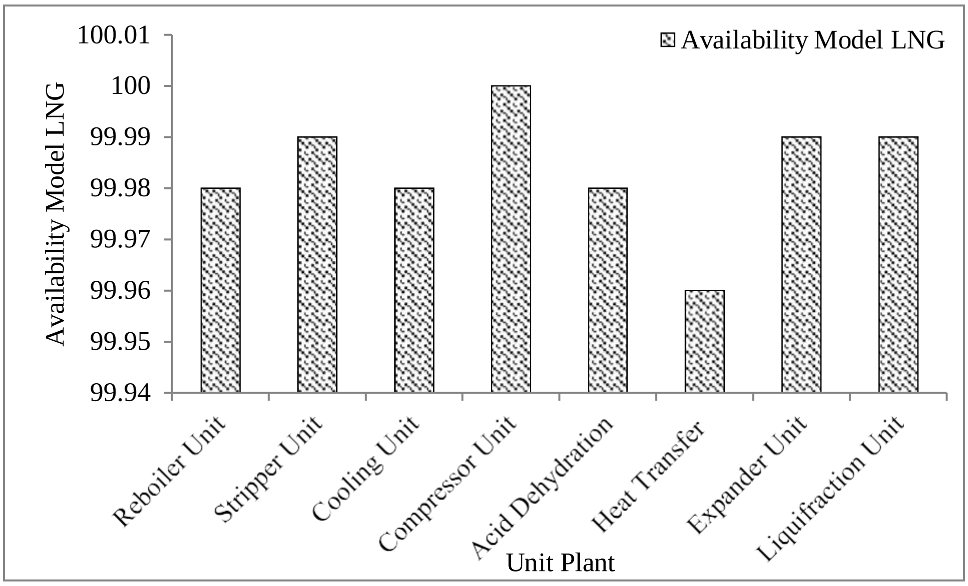

Figure 11. Graph of availability model LNG (%)

Figure 11 illustrates the breakdown maintenance of each unit plant in the liquefied natural gas plant operation. The results obtained in terms of the breakdown maintenance cost against the unit plant their order of magnitude is described as heat transfer unit > cooling unit > acid dehydration unit > stripper unit ≥ expander unit > reboiler unit ≥ liquefraction unit > compressor unit. The variation of the breakdown maintenance cost of each unit plant of the liquefied natural gas plant can be attributed to the variation in the number of failure of each unit plant as well as operational conditions and other factors.

CONCLUSION

Conclusion was drawn from the investigation as demonstrated:

1. This research was able to address the significance of reliability in a Liquefied Natural Gas (NLNG) plant unit in terms of lost time per year, corrective time per failure and the train unit plant functional parameters failure.
2. The study reveals the unit of plant with maximum failure and the factors that contributes to the constant increase in unreliability as well as the measures to control and reduce the occurrence of such event in each of the unit plants.

Considering this research work, the following recommendations are proposed for further research work to be carried out as stated below

i. Reliability analysis should be conducted on the company policy in terms of procedures for faulty items maintainability
ii. Intensive research work should be carried out to examine the quality of parts used during repairs of failed item in each unit plant.

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