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DEVELOPMENT OF ONLINE CHILLER MAINTENANCE MANAGEMENT SYSTEM FOR ENERGY SAVING

A case study of Songas Limited- Ubungo Power Plant
Dar es Salaam, Tanzania

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Abstract: The development of the online chiller maintenance management system for energy saving at Songas Limited becoming of vital thing. The paper explains the problem that resulted into loss of about 5MW from the total Megawatts required to be generated in the Grid, the loss that led to increasing of power rationing in power system of Tanzania. The paper intends to develop online chiller maintenance management system for energy saving at Songas Limited. The established factors were Maintenance policy, Materials control, Work order system, Job planning and scheduling, organization and human resources, reliability, and effective maintenance management system. The approved model was done by partitioning the collected information that were isolated into two parts and the results of the coefficient of determination R^2 is 87.2% for the model development and R^2 is 84.3% for validation data. Second specific objective was to develop an appropriate model for making chiller equipment. The analysis of data was conducted using Statistical Package for the social sciences (SPSS). The results appeared that, R^2 was 87.2% and the Durbin Watson was 2.401, which was between 1.5 and 2.5. The Pressure (P) estimated was between the agreeable margins. Therefore, the variables were found to be valid and reliable for the model and to predict the reliability of the chiller equipment. The system developed is capable to perform the online gas leakage status by monitoring the evaporator approach temperature. Evaporator Approach temperature should not exceed 5°C provided that all condenser fins are free from foulants for maintaining the required Evaporator Gas pressure (EVP), otherwise, there is a gas leakage on low pressure side. However, leakages and cooling fan that resulting into higher-than-normal condenser temperature should be fixed in advances. To ensure online cleaning performs and operate within the required Condenser Gas Temperature (CGT), the water tank should be filled with water all the time. This system may be applied to all air-cooling condenser chiller found in area like Songas limited.

Key Words: *Songas Limited, Grid System (GS), online chiller maintenance management system, Evaporator Gas pressure (EVP), Durbin Watson, Condenser Gas Temperature (CGT), Approach temperature.*

1.0 INTRODUCTION

Under the current situation of global warming, the use of hydropower system to generate electricity is insufficient, since, in some areas of the world the water resources are limited or decreased as well daily [1]. This deficit leads to the use of a Gas turbine (GT) to maintain increased demand for electrical energy. For aircraft engine propulsion, land-based power generation, and industrial applications, the gas turbine has been extensively utilized. As the Rotor Inlet Temperatures (RIT) of a gas turbine rise, so does its power output and thermal efficiency. Currently, advanced gas turbines operate at a Rotor Inlet Temperature that is significantly higher than the yielding point of the blade material, which is approximately 1200°C. Therefore, turbine rotor blade needs to be cooled by 3-5% of High-Pressure Compressor (HPC) air around 700°C during operation of power generation. In a study by [2], they concluded that the interest in inlet air cooling systems for gas turbines has increased in recent years due to the increasing need for power to a low specific investment cost, especially during the summer when the ambient temperature is high. Various methods are used to cool the inlet air to the gas turbine including the use of spray inlet coolers also known as sprint, water passes through atomizer and injected into nozzles and crates mists. Another cooling system is called absorption chillers where a heat removed from air by means of cooled water that passes through the coil of which air to be cooled passes over it. The GT output power strongly depends on the inlet air mass flow rate and according to a survey carried out in Iran the total capacity of power output was reduced by 80% as a lost during hot season [2]. *Chillers* are machines that remove heat from a liquid coolant via a vapor-compression, adsorption refrigeration, or absorption refrigeration cycles. Online Chiller Maintenance.

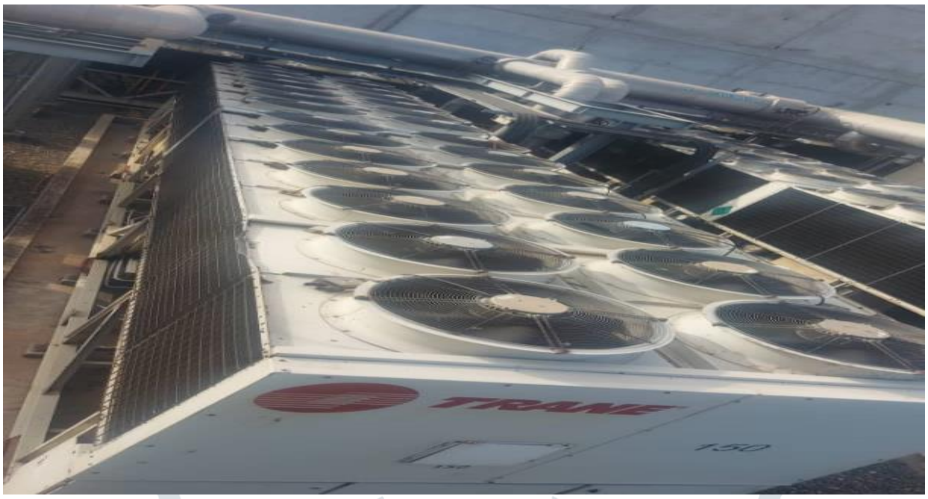

Figure 1.1: Chillers installed at Songas premises (Photo taken by camera on site visit)

About 5MW on a grid that can cause power rationing. Therefore, this paper focuses on developing online chiller maintenance management system suitable for energy saving. Specifically, the paper assesses current maintenance management factors that influence the water scarcity in the power plant as the cooling medium for the condensation of the exhaust steam, together with an increased emphasis on environmental considerations, has made the selection of an air-cooled condenser a viable alternative to the traditional steam surface or water-cooled condenser. Although, their capacity is sometimes limited by ambient conditions, their selection can avoid several problems [3]. Air cooled condenser finned-tube condensers are widely used in refrigeration and air-conditioning applications. For the same amount of heat transfer, the operation of air-cooled condensers is more economic as compared with water cooled condensers typically air-cooled condensers are of the round tube and fin type. To improve the performance of air-cooled condensers multiple techniques can be achieves such as enhancements on inner pipe surface, changing the tube geometry from round to flat shape and external fins. Maintenance interval of a chiller if optimized and automated could reduce the energy waste cost as well as improving the efficiency of the gas turbine by cooling well inlet air and enhance the output energy. The higher the energy output the higher the revenue [4]. Currently, maintenance of the chiller plant at various power plants is conducted by means of High-Pressure Hand Lance, this method offers low water consumption and high-water pressure, unfortunately sometime causes the galvanized surfaces to become damaged or fins to be snapped off. As with the use of Fire Hose this method offers a small improvement in performance and once the fouling material has been compressed, it hinders heat transfer and obstructs air flow also cause loss of production hours due to offline service, in contrary to an automated cleaning machine that performs its operations while the unit is online. [5]. By applying high Pressure Hand Lance methods of maintenance, Songas limited also experience loss of production, high energy waste and high maintenance cost. This issue, is no longer tolerable, losing unwavering quality of chiller; develops the appropriate model for online chiller maintenance management and finally develops online chiller maintenance management system that will spare the energy wastage at Songas limited. Therefore, tolerating above 5MW deficit at Songas, just because of maintenance is like deciding to stop Somanga Gas Plant of 5MW full capacity according to [6].

Figure 1.2: Photo taken at Songas showing megawatt loss when chiller is not timely maintained

The water scarcity in the power plant as the cooling medium for the condensation of the exhaust steam, together with an increased emphasis on environmental considerations, has made the selection of an air-cooled condenser a viable alternative to the traditional steam surface or water-cooled condenser. Although, their capacity is sometimes limited by ambient conditions, their selection can avoid several problems [3]. Air cooled condenser finned-tube condensers are widely used in refrigeration and air-conditioning applications. For the same amount of heat transfer, the operation of air-cooled condensers is more economic as compared with water cooled condensers typically air-cooled condensers are of the round tube and fin type. To improve the performance of air-cooled condensers multiple techniques can be achieves such as enhancements on inner pipe surface, changing the tube geometry from round to flat shape and external fins. Maintenance interval of a chiller if optimized and automated could reduce the energy waste cost as well as improving the efficiency of the gas turbine by cooling well inlet air and enhance the output energy. The higher the energy output the higher the revenue [4]. Currently, maintenance of the chiller plant at various power plants is conducted by means of High-Pressure Hand Lance, this method offers low water consumption and high-water pressure, unfortunately sometime causes the galvanized surfaces to become damaged or fins to be snapped off. As with the use of Fire Hose this method offers a small improvement in performance and once the fouling material has been compressed, it hinders heat transfer and obstructs air flow also cause loss of production hours due to offline service, in contrary to an automated cleaning machine that performs its operations while the unit is online. [5]. By applying high Pressure Hand Lance methods of maintenance, Songas limited also experience loss of production, high energy waste and high maintenance cost. This issue, is no longer tolerable, losing about 5MW on a grid that can cause power rationing. Therefore, this paper focuses on developing online chiller maintenance management system suitable for energy saving. Specifically, the paper assesses current maintenance management factors that influence unwavering quality of chiller; develops the appropriate model for online chiller maintenance management and finally develops online chiller maintenance management system that will spare the energy wastage at Songas limited. Therefore, tolerating above 5MW deficit at Songas, just because of maintenance is like deciding to stop Somanga Gas Plant of 5MW full capacity according to [6].

2.0 LITERATURE REVIEW

2.1 Overview of existing chiller maintenance

Chiller plant is the machine that removes heat from a liquid coolant via a vapor -compression, adsorption refrigeration or, absorption refrigeration cycles. According to [7], chillers are categorized into three types (a) Air-cooled chillers type (b) Water cooled chillers (c) Evaporative chillers.

2.2 Air-cooled chillers type

Agreeing to [8], air-cooled chillers are for the most part the major power customers in air-conditioned buildings within the subtropical climate. To move forward the vitality productivity of the air-cooled chillers at portion stack conditions, two or more refrigeration circuits are designed. [7], considers how the use of optimal circuit loading sequence in the type of chiller that uses ambient air as the condensing source and a fan that moves the air over the coil whilst showing the growing demand for water for both domestic and industrial uses has brought an increased interest in use of air-cooled condensers. According to the studies by [9] and by [10] it is found that there is degradation in performance of air-cooled condenser under high ambient temperatures and windy conditions. The heat rate of ACC also depends on surface condition of fins and thus its performance is reduced due to external fouling of finned tubes due to weather conditions and by internal fouling form condensate (Ammonia Corrosion). Therefore, the review of condenser maintenance is vital.

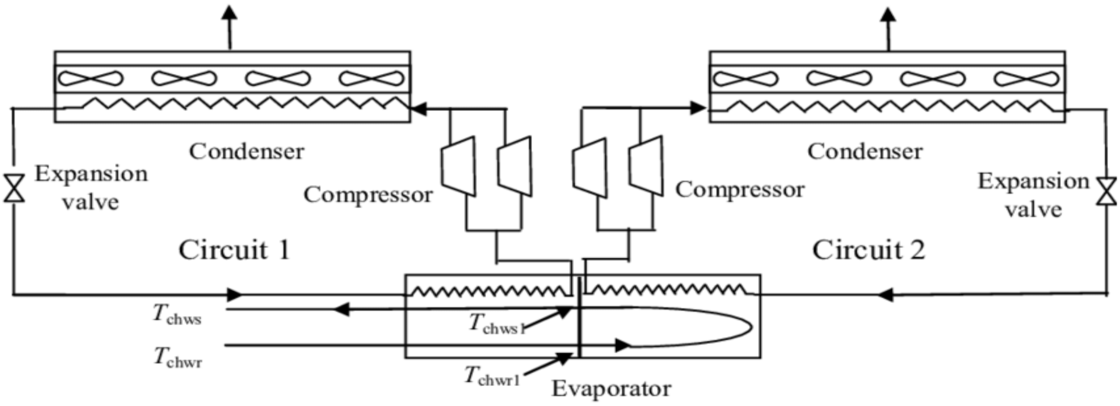

Figure 2.1: Schematic diagram of twin circuit air cooled chiller. [11]

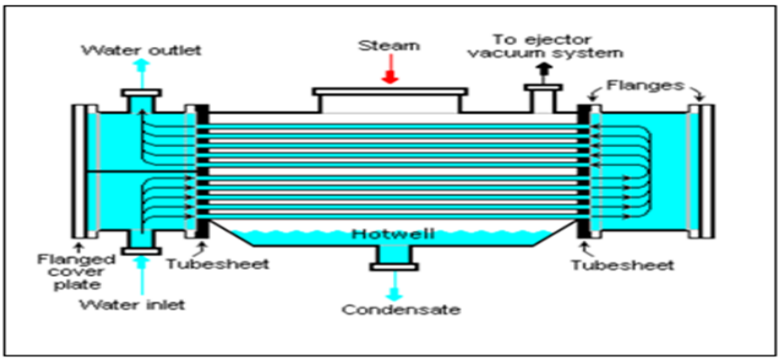

Figure 2.2: Diagram of a typical water-cooled surface condenser [12]

2.3 Online Maintenance system for water-cooled condenser

According to [4] Maintenance of water-cooled condenser is mainly all about cleaning of the internal tubes. Heat exchanger tubes can be cleaned by offline mechanical cleaning methods while the plant is shut down. However, several problems make the off-line methods undesirable. First, there is a loss of production caused by the plants shut down, which may occur as often. Second as soon as chiller is brought back to operation after cleaning, the foulants will gradually build up and cause the plant operating at a low efficiency for a prolonged period until the next schedule maintenance [13]. Lastly, scale and corrosion products attach strongly to the surface over a long period of deposition. Abrasive cleaners, required to remove such deposits, may damage the surface or coating, and thus promote pitting corrosion. According to the study by [14], the problems mentioned can be resolved by using online mechanical systems which enable the cleaning progress to take place while the plant is in operation. The cleaning frequency is much high as many as 12 times per hour, so that the tubes are always maintained clean. According to [15] there are two such kind of systems available in the market for water cooled condenser cleaning that are Brush-and basket type -Used for small heat exchanger and Sponge-ball type- are more appropriate for large heat exchangers, such as those in power plant applications.

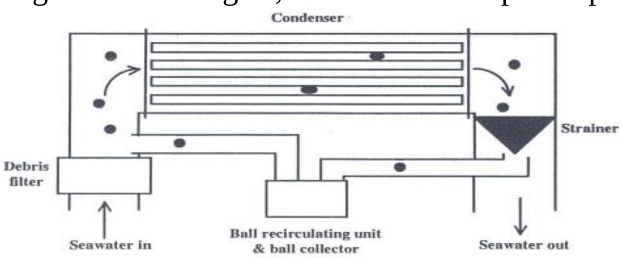

Figure 2.3: Sponge-ball automatic tube cleaning system [16] and Sponge-balls of different size [17]

2.3.1 On-line sponge balls

A sponge ball automatic internal tube cleaning device, conventionally used for power plant, can effectively maintain low fouling factor in a seawater-cooled chiller condenser resulting in enhanced coefficient of performance (COP). It is an online mechanical cleaning device, in which rubber balls serve as tube cleaners [16]. For the first sponge-ball system in Hong Kong, the overall COP is improved by 12% with a payback period of less than 3 years. Besides, the sponge-ball system eliminates the loss of production due to chiller shut down for periodic manual tube cleaning. However, according to [14] using sponge-ball type is accompanied with irregular cleaning of tubes outside main streams area, sponge balls wear and tear and high operating costs.

2.3.2 Online maintenance system for Air-cooled condenser

The study by [18] suggested that where cooling water is in short supply, an air-cooled condenser is often used. An air-cooled condenser is, however, significantly more expensive and cannot achieve as low a steam turbine exhaust pressure (and temperature) as a water-cooled surface condenser. However, the study by [19] cooled condensers were to begin with presented into the U.S control industry within the early 1970’s but as it were started to extend in ubiquity amid the final three decade, to amend debasements in execution related with outside fouling, several cleaning methods are portrayed. Included among these are details of new automated cleaning technology that has been successfully applied, and some of the performance improvements that have resulted from the use of this technique is presented.

2.4 Fouling tendencies

On talk of cooled condensers, the finned tubes outside surfaces are especially helpless to fouling from things like winged animal carcasses, tidy, clean, frightening crawlies, clears out, and plastic sacks. In expansion to the warm exchange coefficient, the debilitating in execution is expanding unit working costs, which isn't impacted by the discussion stream.

2.5 Cleaning techniques for air cooled condenser

Figure 2.4 and figure 2.5 shows example of cleaning technics applicable. Disadvantage of technic shown in figure 2.4 is that it uses plenty of water, but also condenser fins may be damaged. While using technique shown in figure 2.5 needs human intervention.

Figure 2.4: High pressure hand lance *[18]*

Figure 2.5: Semi-Automatic System *[18]*

3.0 METHODOLOGY

To fulfill the study objectives of this paper, distinctive strategies of data collection were embraced such as questionnaire, documentary review, interviews, and field observation and/or direct measurements. Both primary and secondary data were collected. Primary data collected amid the genuine hands-on work by utilizing the measuring tools and information collected, personal interviews, questionnaire, and physical field observation. Secondary data were collected from the case study area Songas limited Tanzania Dar es Salaam documents and from different books, journal, and internet materials.

4.0 DATA COLLECTION AND ANALYSIS

The results obtained were analyzed using computer software known as Statistical Package for Social Sciences (SPSS) [20] and [21] and details output of the data are presented as a series of figures and tables.

4.1 Data collected from the field Observation

Name of Equipment: Chiller equipment, Number of chillers attended: 6

Their ID number: Chiller 110, Chiller 120, Chiller 130, Chiller 140, Chiller 150, Chiller 160

Respectively S/N: EKT4321, EKT4322, EKT4323, EKT4323, EKT4324, EKT4325, EKT4326

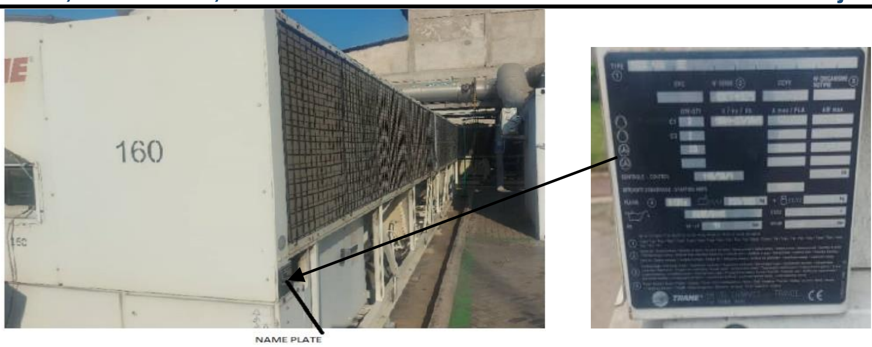

Figure 4.1: Overview of one of chiller and its name plate at Songas limited

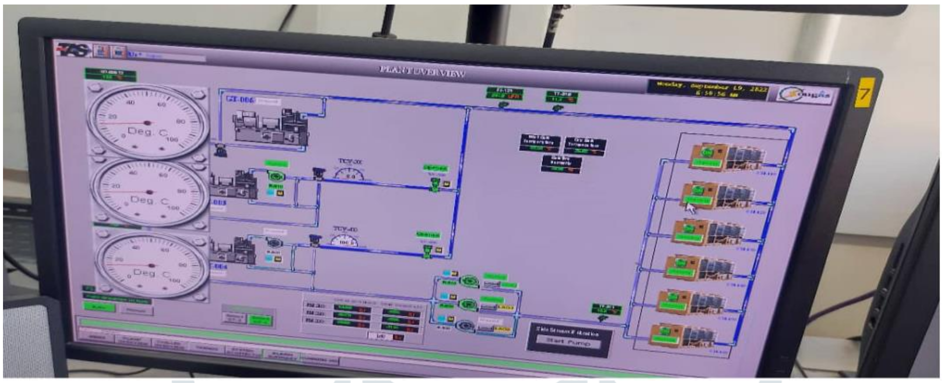

Figure 4.2: View of the Chiller display on DCS system where temperature and flow rate can be Seen located in the control room

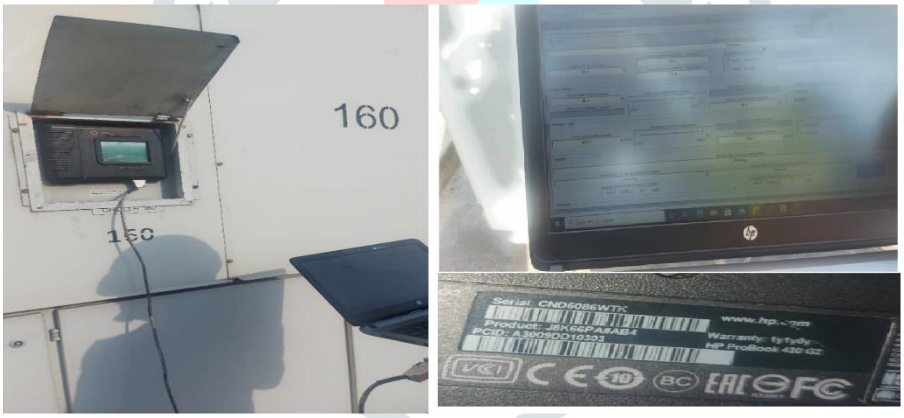

Figure 4.3: View laptop retrieving data from the HMI DynaView adaptive controller of chiller no. 160 at Songas ltd

Table 4.1: Variable influencing equipment reliability

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	**Very Low**	**26**	**37.1**	**46.4**	**46.4**
	Medium	16	22.9	28.6	75.0
	High	8	11.4	14.8	89.8
	Very High	6	8.6	10.7	100.0
	Total	56	80	100.0	
Missing	System	14	20		
Total		70	100.0		

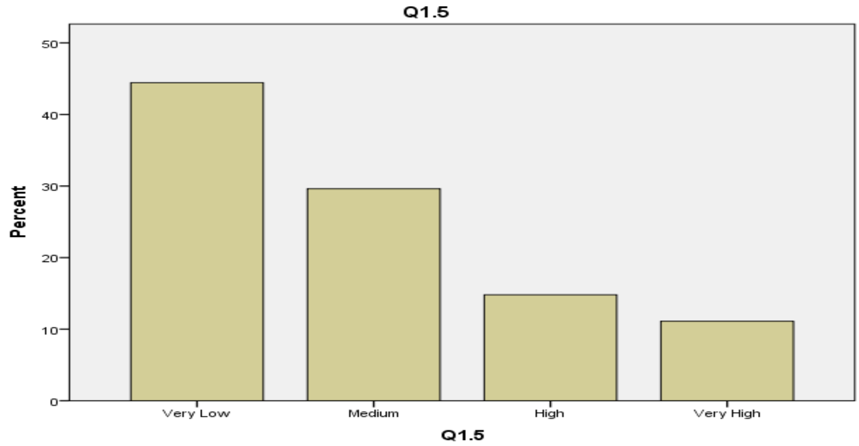

Figure 4.4: Percentage of effectiveness of maintenance management system

4.2. Examination of factors influencing Hardware Unwavering quality

These variables were tested statistically. By utilizing Likert Scale, statistical analysis was prepared as the scale was set 4-points, that's; 1 being "very low", 2 being "low" 3 being "moderate" and 4 being "high". The mean of Likert Scale was equal to 2.5, that is {(1+2+3+4)/4}. From mean it can be statistically compared that an esteem underneath 2.5 implies the factors influencing maintenance management system at Songas limited is to the low extent and the value above 2.5 means the variable is the high.

5.0 DEVELOPMENT OF MAINTENANCE MANAGEMENT MODEL

5.1. Contribution of various factors affecting chiller cooling performance Reliability

Although, there are many factors that affect reliable the leaving water temperature is, only five have been considered, and their combined effects are what determine the dependability of the chiller. It is crucial to understand each variable's contribution in relation to the others by giving each one coefficient because the effects of these variables are not all the same. It is important to realize that these variables interact with one another, which eventually has an impact on reliability. These factors' combined effects are determined by adding their individual coefficients to their sum. Therefore, assuming a linear relationship between these variables and the data that show a negative coefficient, an increase in X is connected to a decrease in Y for any variables X and Y. an increase in X is correlated with a fall in Y. a Negative number indicates a relationship between two variables I the same way a positive coefficient does, and the relative strengths are the same. Hence the total effect equation is given as

F(EVP) = (Y + 67)/1.225. It is crucial to understand each variable's contribution in relation to the others by giving each one coefficient because the effects of these variables are not all the same. The entire yield of these factors is the combination of all factors. R = 0.854 Z2 + 0.129 M 1 – 0.071 Durbin – Watson between 1.5 and 2.5, showing the nonattendance of auto relationship and R2 of (0.872) that's 87.2 in percentage

But,

$\beta\ 0 = \beta\ 3 = \beta\ 4 = \beta\ 5 = \beta\ 6 = 0$

$\beta\ 1 = 1.225$

$\beta\ 2 = -1.00$

$Y = 1.225EVP - CGT$

The over output

$$F(EVP) = \begin{cases} 0. & 60 \leq EVP < 69, \\ 1. & 69 \leq EVP \end{cases}$$

Developed system.

Whereby,

F(EVP) = (Y + 67)/1.225

F(EVP) = Function of Evaporator pressure

Y = output/leaving water temperature.

6.0 DEVELOPMENT OF MAINTENANCE MANAGEMENT SYSTEM

The developed online chiller maintenance system works as per flow charts, it complies with four states OFF states, active states, leakage check, tank filling and cleaning process.

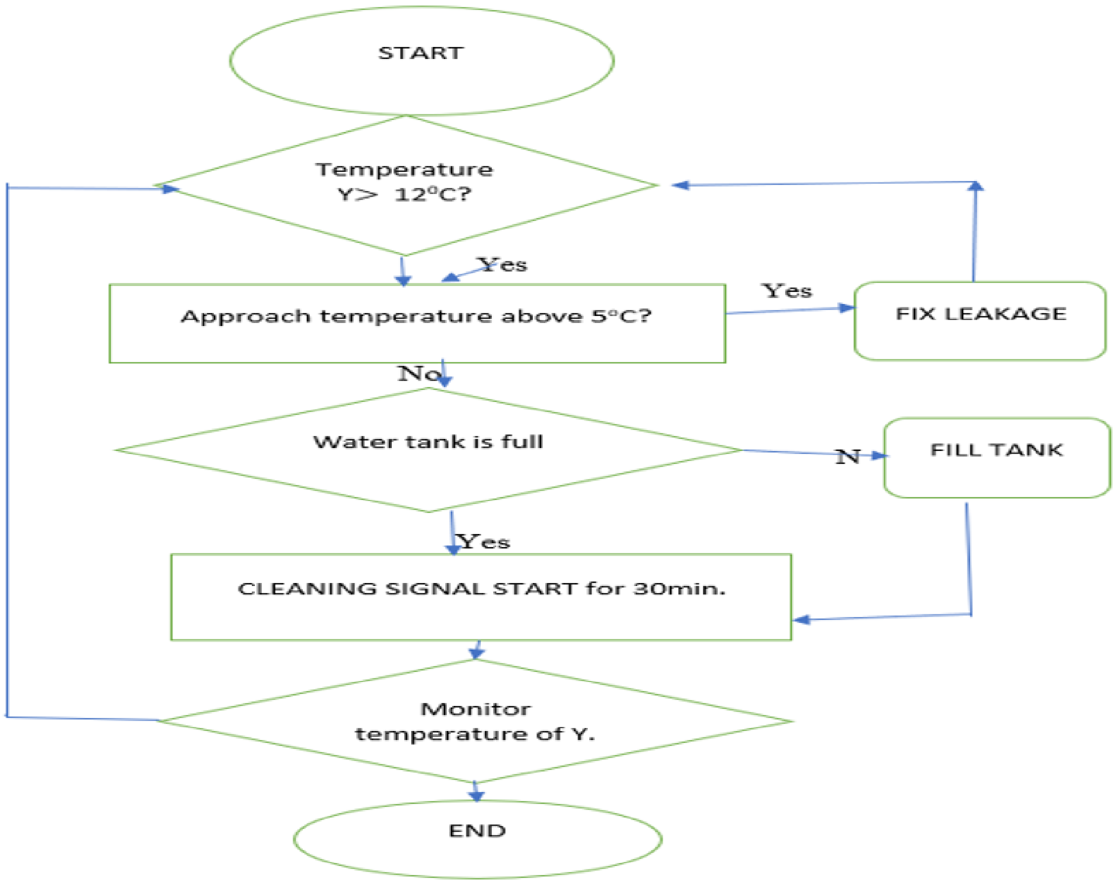

Figure 4.5: Flow chart of the online maintenance management system

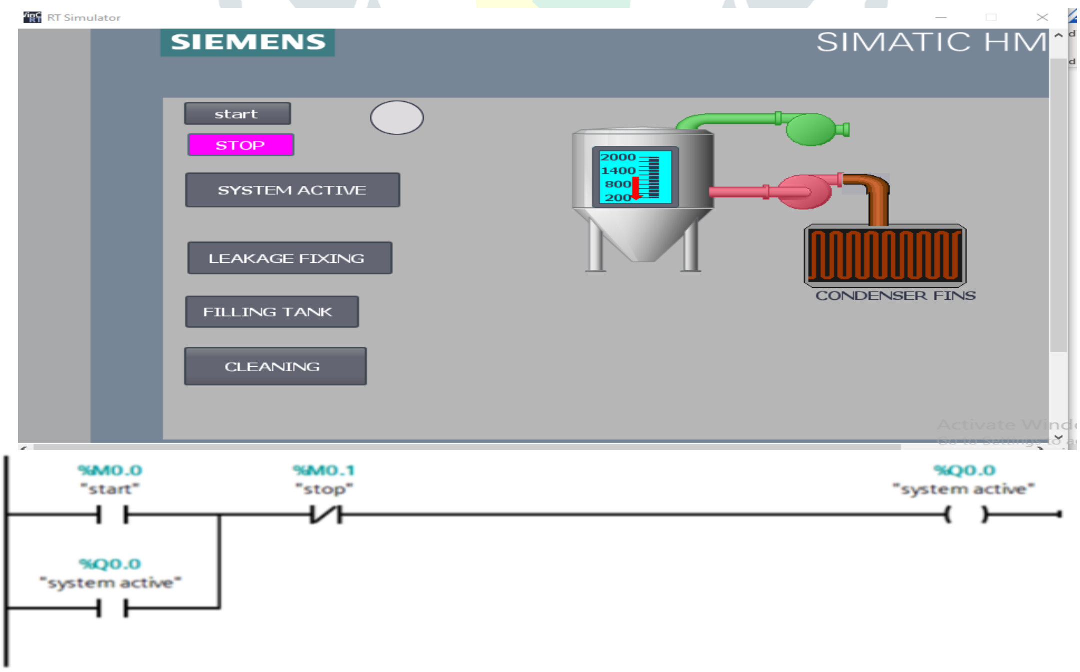

Figure 4.6: Online Chiller Maintenance Management System developed before in off state

6.1 Working Principles of Online Chiller Maintenance Management System

Since the unit understand 0 and 1 binary numbers, the F(EVP) is ZERO when the value of leaving water temperature Y will be computed less than 13°C but greater to or equal to 7°C, let say the function of the temperature and pressure go higher beyond the range, the system is capable to compute, compare output temperature thereafter outputs binary signal whether to initiate the process or not. Moreover, the online system developed remains inactive when the output temperature of the leaving water is less that 7°C assuming that the freezing protection takes control by the DynaView itself. Below 7°C system is undecided, between 7°C and 13°C, the system output Zero, and any temperature above 13°C causing the system to become high and activates the cleaning signal to start. The system is capable to perform the online gas leakage status by monitoring the approach temperature, Approach temperature should not exceed 5°C otherwise, there is a gas leakage evaporator.

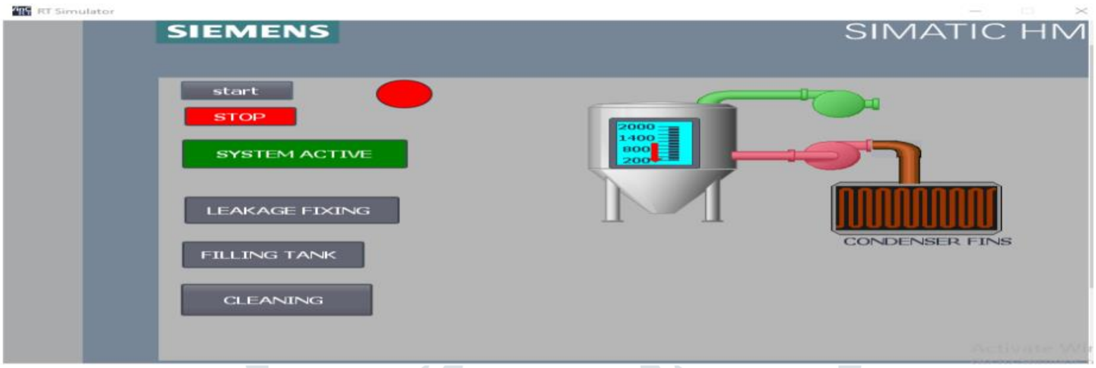

Figure 4.7: Online Chiller Maintenance Management System developed in active state

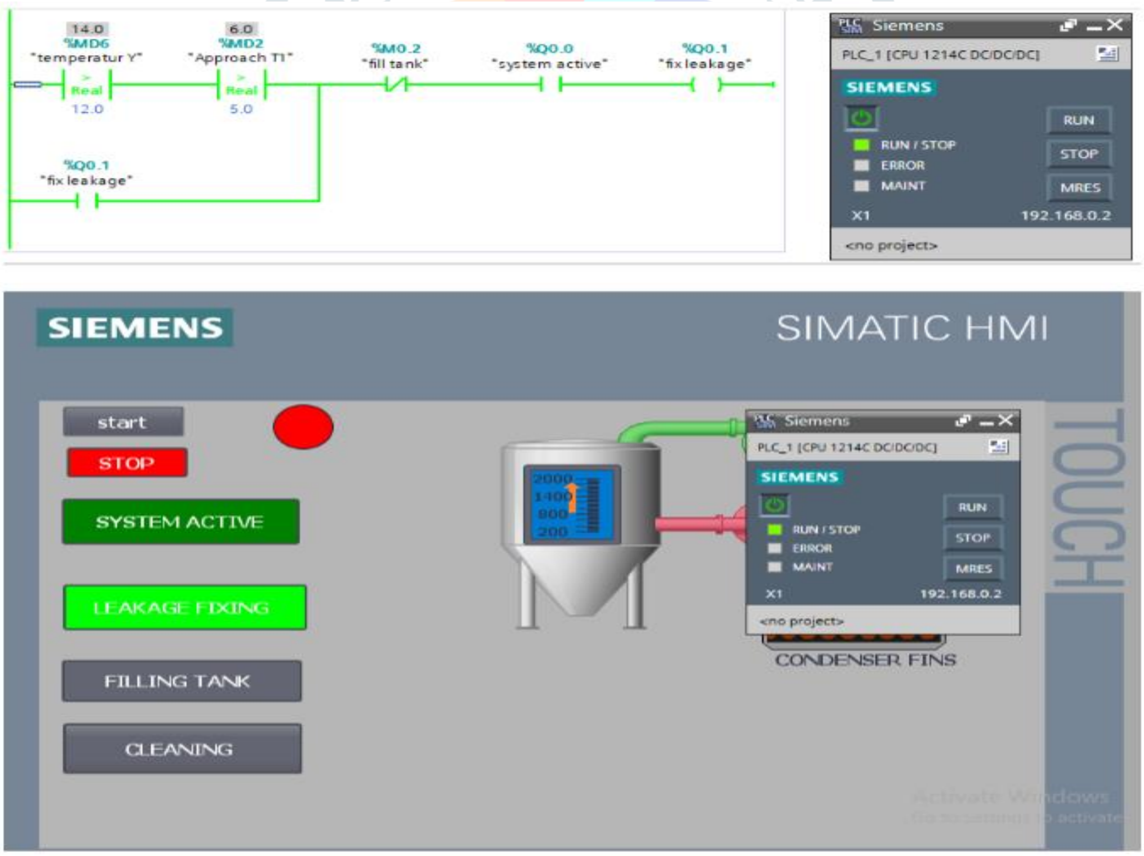

Figure 4.8: Online Chiller Maintenance System developed before in leakage fixing state

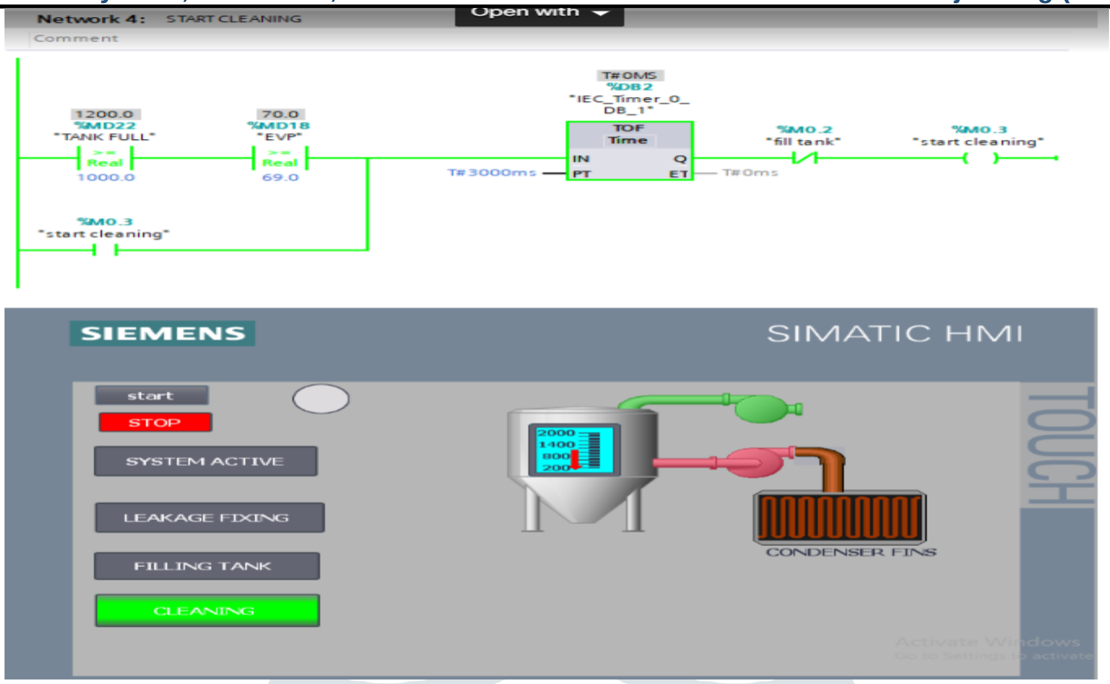

Figure 4.9: Online Chiller Maintenance System developed before in cleaning state

Evaluation of EVP = (Y + 67) / 1.225

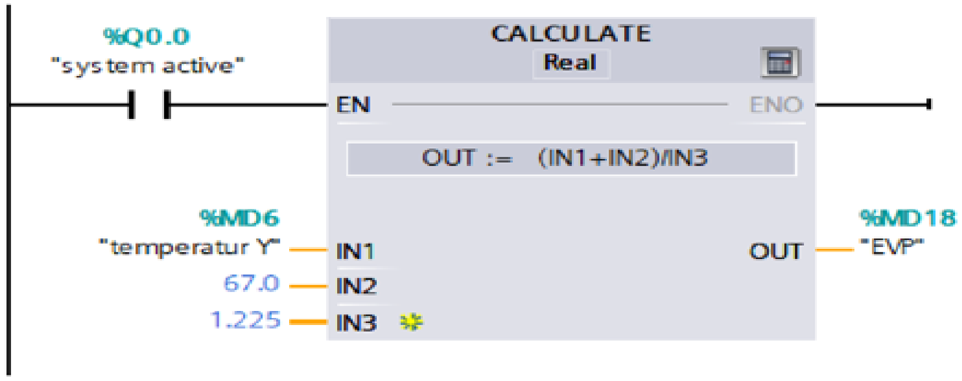

Figure 4.10: Online Chiller Maintenance System developed instruction for temperature monitor

7.0 RESULTS AND DISCUSSION

7.1 Results

The system developed showed high capability of resolving energy wastage by reducing it from 48hours as downtime to zero during the manual practice. Also, no need of worry regarding manpower, because once the system was kept on every sequence goes automatic as supposed to do however, there is a need of having water tank of clean water connected to the system. The system developed works independent of the DynaView (chiller HMI and microprocessor) except during emergencies and fault occasion, whereby developed chiller keeps watching and terminate the online process through it is critical path interruption.

The paper reveals that the maintenance system for chiller system at Songas Ltd was not robotized to work online while the chiller is still working, however it was done physically after total isolation of the control supply and Lock Out and Tag Out (LOTO). The existing maintenance took long time to accomplish entire process, but the development took lid of the time wastage problem. Thus, it was found that process proved that it not capable to overcome the accumulation of the dust on the condenser fins, as a result in most of time the chiller was running under low efficiency causing its reliability to drop, affecting power cooling of the Rotor Inlet Temperature (RIT) of the Gas turbine eventually reducing Megawatts generation. The achievement of this paper was realized by developing online maintenance management system consolidated with the field detected parameters, from there on comparing with the worthy ranges for chiller operation and on the off chance that it goes past the run. The system was tested as well with temperature high outlet water temperature , the system was competent to compute, compare at that point yield parallel action to whether to start the process or not. Apart from the online system created remains inert when the output temperature of the leaving water is less than 7°C the critical path takes control by DynaView itself. That's to say, whenever the outlet temp below 7°C detected the developed system remains undecided. However, the antifreeze protection activated by chiller DynaView controller to minimize the possibility of tubes damage. Between 7°C and 13°C, the developed system yields zero, and the temperature over

13ºC causing the system to initiate the online maintenance process. The system was capable to perform the online gas leakage status by monitoring the approach temperature, Approach temperature should not exceed 5ºC otherwise, there is a gas leakage evaporator. To ensure online cleaning is performed and hence to operate within the required temperature CGT the water tank should be filled with water all the time. Moreover, the organization must put in consideration the equipment and machinery in terms of age, misuse, maintainability, similarities of the machine and involving maintenance department at an early stage when new equipment are purchased to design reliability and maintainability of equipment. This could help improving the Reliability of chiller equipment. Therefore, the safety and operation should be considered to make sure that reliability is maintained. For maintaining the required Evaporator Gas pressure EVP, leakages should be fixed in advances and cooling fan resulting into leakages should be fixed. Since chiller condenser always contain compressed refrigerant gas, its temperature is high. The developed system assumed that the water to be used will always have less difference from that of the condenser. To avoid any damage due to contraction and expansion caused be temperature difference.
To ensure online cleaning is performed and hence to operate within the required temperature CGT the water tank should be filled with water all the time. Moreover, the organization must put in consideration the equipment and machinery in terms of age, misuse, maintainability, similarities of the machine and involving maintenance department at an early stage when new equipment are purchased to design reliability and maintainability of equipment. This could help improving the Reliability of chiller equipment. Therefore, the safety and operation should be considered to make sure that reliability is maintained. And for maintaining the required Evaporator Gas pressure EVP, leakages should be fixed in advances and cooling fan resulting into leakages should be fixed.

7.2 Discussion

The paper revealed all factors that affecting the availability and reliability of the chiller at Songas, the online system model obtain was R = 0.854 Z2 + 0.129 M 1 – 0.071, however the overall online chiller maintenance system developed from system equation developed as a function of gas and temperature given as Evaluation of Evaporator gas Pressure (EVP) = (Y + 67) / 1.225 and work as the flow charts explained. The developed system plays a big role in contribution of energy saving. The energy that would have been lost due high consumption of unmaintained chiller and the energy that could be generated by gas turbine when its inlet compulsion air not well cooled. In Tanzania wastage of more that 5MW is something terrible. It might be just like deciding to close the entire power plant at Somanga Funga with plant capacity of 5MW. Contribution of 5MW in nation grid, reduces the power rationing in the street, since Power ration in Tanzania nowadays is almost daily issue especially during weekdays, this ration causes a great impact economically, socially as well as environmentally. For instance, Somanga Gas Plant located in Lindi Region Kilwa District at Somanga Fungu Village. the available capacity is 5MW for two generating units no.1&2, and the maximum demand to date is 2.43 8 MW. Therefore, in simple words tolerating 5MW deficit at Songas just because of maintenance practicing is like deciding to stop Somanga Gas Plant. (TANESCO, 2021) (a) Economically - it is uneconomical to run gas turbine while the inlet air temperature is high just because cooling from chillers is insufficient and unfortunately chillers require maintenance while offline maintenance schedule is not due, the heat rates become high unnecessary causing loss of money after being penalized by relevant authorities. Also, revenue loss of more than 5MW is something critical to power plant and to national economic because 5MW can supply even one region and raise individual economy for habitants.. (b) Socially- due to unexpected power rationing people do not enjoy they social life, scarcity of cold drinks, lacking power for air conditioning system caused uncomfortable to people. But also, in hospitals things become worse sometimes if power rationing occurred without pre information. Student failed to have their person learning due to power rationing hence affect the class performance (c) Environmentally -with proper cooling of the air inlet the substances that occur in combustion gases when are burned include (NOx) this contribute to ground level ozone, which irritates and damages the lungs. CO_2 is a greenhouse gas which contributes to the greenhouse effect. Nearly all combustion by products has negative effects on the environment and human health.[9]. Moreover, to maintain hygiene becomes tough issue because water needs electrical power to be pumped. Therefore, Songas limited must employ online chiller maintenance system for energy saving in Songas power plant, out of which may contribute to economic, social, environmental relief to citizen of Tanzania.

8.0 CONCLUSION AND RECOMMENDATIONS

In this paper, A multiple regressions model was formulated to be used for predicting and explaining the reliability of the equipment, and this model can be used to improve the service by making sure that the chiller equipment is available and reliable all the time. The assessment results can be used to explore more reliability improvement opportunities. When the chiller is maintained online, its availability increases and as a result the cooling turbine inlet air temperature extended, eventually energy generated by gas turbine increases at the same time chiller consume less amount of energy (energy saving is maximized).

8.1 Conclusion

The online chiller maintenance Management system developed can provides adequate, timely, uniformly cleaning of condenser fins automatically whenever the maintenance requirements conditions fulfilled. The time of condenser cleaning takes almost 2hours only without switching of the chiller, unlike the previous manual practice which took almost 8hours per single chiller with chiller off.

8.2 Recommendations

This developed system requires clean water for cleaning of the condenser fins to avoid corrosion, Thus, all make sure that tank is full of clean water. Moreover, to avoid the effects of rapid change of temperature on condenser tubes causing (tubes damage) during cleaning, avoid using extremely cold water on hot condenser pipes.

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