Reduction of Breakdown for Gas Turbine in Combined Cycle Power Plant

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***Abstract*—The objective of this research is to reduce the breakdown for the gas turbine in a combined cycle power plant through the collected gas turbine breakdown. The use of Pareto diagram is apply to select the issues. The electricity production in the current condition is then studied by focusing on the operation, equipment, and other machinery that affect breakdowns. The breakdown causes are then analyzed using be cause and effect diagram. The failure mode and effect analysis (FMEA) is then performed to determine the cause of the breakdown. The criteria are set and evaluated to calculate the risk priority number (RPN) to prioritize the selection of the breakdown causes that need to be improved. It is found that the current availability increased by 1.47% and the amount of breakdowns cost in power generation decreased by 79%.**

***Index Terms*—machine breakdown, failure mode and effect analysis, maintenance, gas turbine, power plant combined cycle power plant**

I. Introduction

Presents the rapid expansion of the community and the growth of technology in the electricity industry is a very important factor particularly the use of electricity in residential,transportation,communication, manufacturing, and industry of all types. This also includes the country economic development, resulting in the demand to use electric power constantly increasing. However, the electricity cannot be stored and the demand for electricity in each period is unequal so the availability of electricity must be continuous. Electricity production must be efficient, and the electricity production readiness are needed to meet the demand for electricity at all time.

An FMEA (Failure Mode and Effect Analysis) is a systematic method of identifying and preventing product and process problems before they occur. [1] As a tool in risk evaluation , FMEA is considered to be a method to identify severity of potential effect of failure and provide an input to mitigating measures to reduce risk. In many application, FMEA also includes an estimation of the probability of occurrence of the cause of failure and their resultant failure mode. This broadens the analysis by providing a measure of the failure mode's likelihood. To minimize risk, the likelihood of failure occurrence is reduced which increase product or process reliability. [2]

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The authors apply FMEA techniques to the electric power industry and strongly studies process in order to analyze and solve the real root cause of the problems for reduce machine breakdown loss.

The case study is a highly effective combined cycle power plant with high production capacity of approximately 119.2 MW.

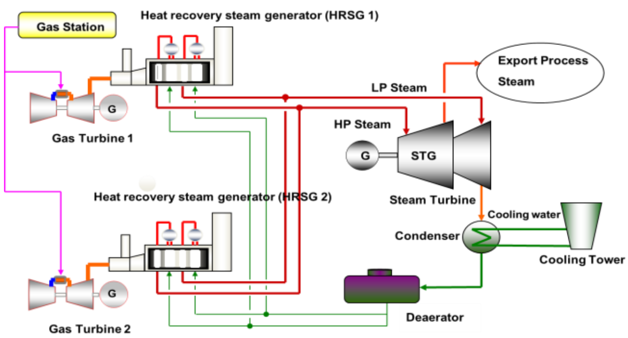

Figure 1. Combined cycle power plant process.

The power plant comprise of 2 gas turbines with production capacity of approximately 47.4. MW, 2 Heat Recover Steam Generators (HRSG) and 1 steam turbine with production capacity of approximately 24.3. MW.

The working process is as follows: a gas turbine engine with a compressor as the main equipment on the same shaft as a turbine gas and a generator. When the engine is turned on, air is drawn from the outside into the compressor until the pressure and temperature rise to be sent to a burning chamber. There is a combustion chamber with fuel injector, which inject natural gas fuel to burn and heat the air inside to increase the gas pressure and temperature, which would then be expanded causing the gas turbine to spin and at the same time drove the compress air of hot gas. This would enable the generator to produce electric power. When the pressure of the hot gas has gone through the gas turbine, the temperature would be reduced to roughly 580-600 ° C. The main components of the stream turbine power generator consist of Heat Recovery Steam Generators (HRSG), stream turbine, condenser, cooling tower, and generator. The functions of the electricity production of the system with steam turbine power generator start with store water that has gone through water treatment plant in the cooling tower to get demin water to refill the boiler that would be heated by the hot gases emit by the gas

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turbine. This results in the water in the boiler changes into a high- energy steam and the steam would be sent to rotate the steam turbine to work up to drive the generator as another way to get electrical power. [3]

II. DEFINE PHASE

As a small power plant (SPP) with the purchase agreement with the Electricity Generating Authority of Thailand, there are nearby factories as customers; the power plant could not continuously supply electricity to customers, resulting in inefficient and instable electricity production cause by breakdowns of the whole power plant. The breakdowns lead to loss in revenue from electricity sales and customer complaints. Each minute of machine breakdown result in very significant effect. Therefore, the authors collect all breakdown information separated by the number of breakdown times and downtime from breakdown of gas turbines 1 and 2 from June to December 2016.

After gathering the mentioned above information, it can be seen that the number of breakdowns for gas Turbine 1 is 16 times and the duration of breakdown time is 4,418 minutes and the number of Breakdowns for gas Turbine 2 is 10 times and the duration of Breakdown time is 1,092 minutes.

With respect to the above information, an improvement shall be made to the breakdown for gas turbine 1. The mean time between failures (MTBF) is estimated to 14, 201 minutes and the Availability is 98.32% which actually a power plant should have high Availability.

Expenses spent on the breakdown for Gas Turbine can be calculated from the cost of operating a machine ($) which calculate from the amount of money paid to the gas cost involve in operating a machine and lost opportunity cost to sell electricity to the market ($) which calculate from the amount of electricity sales during off peak and peak times in each month. The table below shows the summary of calculation.

TABLE I. ALL EXPENSES SPENT ON THE BREAKDOWN FOR GAS TURBINE 1 FROM JUNE TO DECEMBER 2016

Month	Cost involved in operating the machine ($)	Lost opportunity cost to sell electricity ($)	All expenses involved in the Breakdown ($)
Jul-16	11,085	72,092	83,177
Aug-16	5,399	19,923	25,337
Sep-16	4,087	6,300	10,387
Oct-16	3,964	9,346	13,310
Nov-16	15,674	153,646	169,320
Dec-16	1,580	5,400	6,980
Total	41,789	266,723	308,512

From the Table, it can be noticed that the cost involved in operating the machine is 41, 789 $, the lost opportunity cost to sell electricity is 266,723 $ which can be calculated as expenses spent on the Breakdown totally 308,512 $.

After the data are collected, an analysis and classification of failure mode for Gas Turbine 1 is shown in Fig. 2.

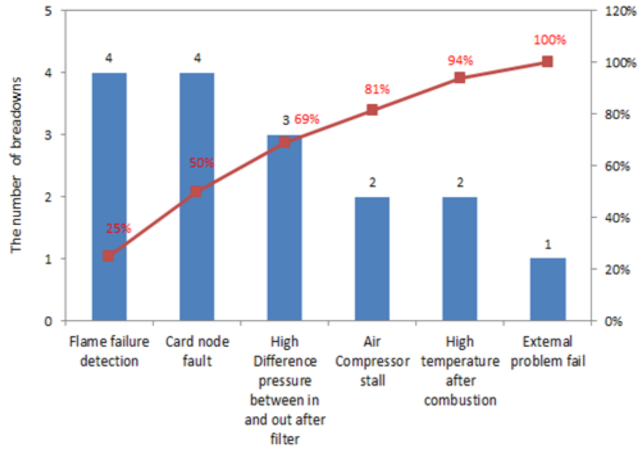

Figure 2. Pareto chart of the failure for Gas Turbine 1

III. ROOT CAUSE ANALYSIS

Root cause analysis (RCA) is a method of problem solving used for identifying the root causes of faults or problems. A factor is considered a root cause if removal thereof from the problem- fault-sequence prevents the final undesirable outcome from recurring; whereas a causal factor is one that affects an event's outcome, but is not a root cause. Though removing a causal factor can benefit an outcome, it does not prevent its recurrence with certainty. [5]

The study aims to analyze, make an understanding and seek a guidance to solve the problems to the right point. It is studied that gas turbine breakdown causes and found the 4 major problems are analyzed flame failure detection , card node fault, High difference pressure between in and out after filtered and compressor stall.

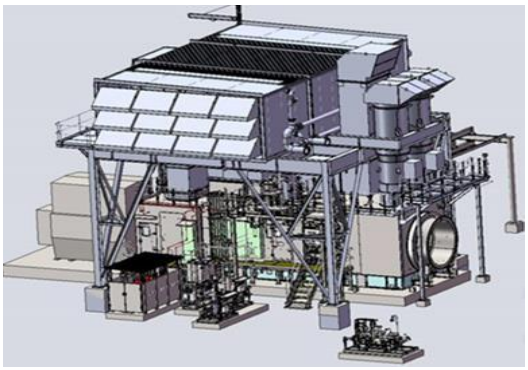

Figure 3. Gas Turbine Package (IHI gas turbine manual,2010)

Causes of failures are analyzed through a cause and effect diagram. The defect is shown as the fish's head, facing to the right, with the causes extending to the left as fishbones; the ribs branch off the backbone for major causes, with sub-branches for root-causes, to as many levels as required [6]

With respect to a brainstorming session with experts and relate person through the cause and effect diagram to find the causes of problems by analyzing 4 major problems affecting the breakdown of the gas turbine, the outcomes can be shown as follow.

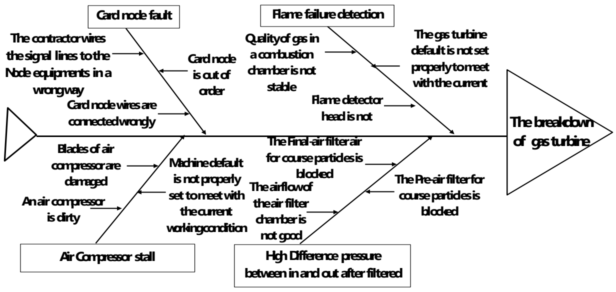

Figure 4. Diagram of causes and effects of the breakdown of the gas turbine

In summary, the cause and effect of problems by analyzing 4 major problems affecting the breakdown of the gas turbine, these can be shown this table.

TABLE II. TABLE OF FAILURE CAUSES

Failure	Failure cause
Flame failure detection	The gas turbine default is not set properly to meet with the current working condition
	Flame detector head is not clean
	Quality of gas in a combustion chamber is not stable
Card node fault	Card node is out of order
	Card node wires are connected wrongly
	The contractor wires the signal lines to the Node equipments in a wrong way
High Difference pressure between in and out after filtered	The airflow of the air filter chamber is not good
	The Pre-air filter for course particles is blocked
	The Final-air filter air for course particles is blocked
	Environmental conditions are not suitable such as being full of wildflowers and dust
Air Compressor stall	Blades of air compressor are damaged
	An air compressor is dirty
	Machine default is not properly set to meet with the current working condition

IV. ANALYSIS PHASE BY FMEA TECHNIQUE

"FMEA" is a shortened form of Failure Mode and Effects Analysis which can be translated in Thai as "an analysis of the cause of failures and effect" by considering what kind of failures that can probably occur, how much those failure can affect, what the cause of failures are, and if there is any failure detection system before entering other process or not, and if there is any difficulty in failure detection. [7]

Process FMEA is utilized to identify potential process failure modes by ranking failures and helping to establish priorities according to the relative impact on the internal or external customer. [8]

Effects of expected damages were analyzed (Effects Analysis) to seek preventive measures (Problems Prevention). Risk assessment was conducted by RPN number (Risk Priority Number); [9] whereas

RPN = S x 0 x D

Where S = Severity

O = Occurrence

D = Ability to detect (Detection)

After knowing the technical data of gas turbine , routine machine failure and the optimal condition for operating machine , the researcher and expert cooperate expert cooperate to make a consideration and improvement criteria and severity level assessment (S), O = Occurrence and D = Ability to redetect and shown in the following table.

TABLE III. FMEA RATING SCALE

Parameter / Score	S	O	D
10	Failure result impacts machine shutdown and unsafe operation	Extremely high occur	Uncontrolled process
8	Failure result impacts machine shutdown	High occur (6-7 Times /6 month)	Failure is detected by machine and equipment check list
6	Machine can operate but reduce operating electricity	Intermediate occur (4-5 Times/6 month)	Failure is detected by fault alarm and special inspected equipment
4	Machine can operate and affects very little of the system	Rarely occur (2-3Times /6 month)	Failure is detected by point fault alarm
2	No effect	Never occur (0-1 Times /6 month)	Failure is detected by automatic detected and safety shutdown system

The risk assessment conducted by RPN number and after the RPN number of the causes of machinery failures is assessed according to the FMEA guideline by choosing from RPN equal to or greater than 192 to improve and correct for reduction of machinery failures as shown in the following table.

TABLE IV. FAILURE MODE AND EFFECTS ANALYSIS OF THE BREAKDOWN OF THE GAS TURBINE

Failure	Potential effects of Failure	S	Potential causes of Failure	O	Current Control Prevention	D	RPN	Improving guidance	After Improvement			
									S	O	D	RPN
Flame failure detection	Gas turbine shutdown	8	Quality of gas in the combustion chamber is not stable	6	Uncontrolled	10	480	Organize a new method to set gas default for a combustion system	8	2	8	128
	Gas turbine shutdown	8	Flame detector head is not clean	4	Not have Observation and checking the machine	10	320	Organize a check sheet and maintenance plan for flame detector equipment	8	2	8	128
	Gas turbine can be operated but with low efficiency.	6	The gas turbine default is not set properly to meet with the current working condition	6	Observation and checking the machine	8	288	Organize a plan for setting the gas turbine default.	6	2	8	96
Card node fault	Gas turbine shutdown	8	Card node are damaged	4	Not have Observation and checking the machine	10	320	Organize a maintenance plan for Card node	8	2	10	160
	Gas turbine shutdown	8	Card node wires are connected wrongly	4	Not have Observation and checking the machine	10	320	Organize a check sheet for Card node	8	2	8	128
	Gas turbine shutdown	8	The contractor wires the signal lines to the Node equipments in a wrong way	4	Not have Observation and checking the machine	10	320	Organize a check sheet for the contractor's working	8	2	8	128
High Difference pressure between in and out after filtered	Gas turbine shutdown sources	8	The filtering of the air filter room is not good	4	The machine show alarm	6	192	Make an improvement of the air filter system for course particles that brought to use from external sources	8	2	6	96
	Gas turbine shutdown	8	The Pre-air filter for course particles is blocked	4	The machine show alarm	6	192	Change a model of Pre-air filter for course particles	8	2	6	96
	Gas turbine shutdown	8	The Final-air filter air for course particles is blocked	4	The machine show alarm	6	192	Change a model of Final-air filter for course particles	8	2	6	96

TABLE V. FAILURE MODE AND EFFECTS ANALYSIS OF THE BREAKDOWN OF THE GAS TURBINE (CONTINUES)

Failure	Potential effects of Failure	S	Potential causes of Failure	O	Current Control Prevention	D	RPN	Improving guidance	After Improvement			
									S	O	D	RPN
Air Compressor stall	Gas turbine shutdown	8	Blades of air compressor are damaged	4	Uncontrolled	10	320	Make an improvement of air compressor maintenance plan	8	2	8	128
	Gas turbine can be operated but with low efficiency	6	An air compressor is dirty	4	Observation and checking the machine	8	192	Organize a plan for cleaning the air compressor	6	2	6	96
	Gas turbine can be operated but with low efficiency	6	Machine default is not properly set to meet with the current working condition	4	Observation and checking the machine	8	192	Organize a plan for setting the gas turbine default	4	2	6	64

Compared the RPN values before and after improvement of total 12 causes of failure. In summary, these cause can reduce less than 192 as shown in the following table.

TABLE VI. RISK PRIORITY NUMBER; RPN BEFORE AND AFTER IMPROVEMENT

Failure	Causes of failure	Before Improvement RPN	After Improvement RPN
Flame failure detection	Quality of gas in the combustion chamber is not stable	480	128
	Flame detector head is not clean	320	128
	The gas turbine default is not set properly to meet with the current working condition	288	96
Card node fault	Card node are damaged	320	160
	Card node wires are connected wrongly	320	128
	The contractor wires the signal lines to the Node equipments in a wrong way	320	128
High Difference pressure between in and out after filtered	The filtering of the air filter room is not good	192	96
	The Pre-air filter for course particles is blocked	192	96
	The Final-air filter air for course particles is blocked	192	96

TABLE VII. RISK PRIORITY NUMBER; RPN BEFORE AND AFTER IMPROVEMENT (CONTINUES)

Failure	Causes of failure	Before Improvement RPN	After Improvement RPN
Air Compressor stall	Blades of air compressor are damaged	320	128
	An air compressor is dirty	192	96
	Machine default is not properly set to meet with the current working condition	192	64

V. CONCLUSION

This research is an analysis to reduce the breakdown for the gas turbine in generating electricity of a combined cycle power plant base on the gathering of all failures found in the gas turbine and the principle of Pareto chart to select problems to solve. The 4 major failures are flame failure detection , card node fault, high difference pressure between in and out after filtered, and air compressor stall. The causes of the breakdown are sought through the cause and effect diagram and analyzed by applying the failure mode and effect analysis technique (FMEA) to find the root cause of failures together. These quality tools can be solve real root causes and reduce breakdown losses for the gas turbine, it is found that the availability at present increases 1.47 % and expenses spent on the cost of the breakdown of the gas turbine can be decreased to 79 %.This study demonstrated a solution that could well solve the overall problem that caused the gas turbine breakdown. However, it was conducted without an in-depth analysis of the machine parts. Other researcher or entrepreneur is recommended to apply the knowledge and use it in a further study on combined cycle power plant, an industry with a great effect to the mass.

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