OPTIMIZATION ON FUEL GAS OPERATION FOR COMBINED CYCLE POWER PLANT

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To my friends and family for your support and advise.

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ABSTRACT

Fuel gas system for 13E2 gas turbine is designed to optimize the fuel gas consumption and reduce nitrogen oxide gas emission. This system consists of closed loop controller, control valves, shut off valves, and burners. Due to long running operation, the hardware of gas turbine efficiency will deteriorate. During major outage, all hardware will be replaced or repaired. Since the characteristic of gas turbine changed, it is not matching with the existing fuel gas system setting. Hence the fuel gas system has to be calibrated. In this project thesis, one of the main targets is to explain the CCGT fundamentals. In the CCGT system, there is a subsystem named as fuel gas control system. This system is selected for improvement purposes. The next main target is to prove that the proposed improvement is possible. The calibration work is focused on the 3 main control valves (MBP 41, 42, and 43). A step by step working instruction is indicated and the trending for relevant signals are displayed and recorded. On top of that, the details of fuel gas system, components, and its operation have been explained. Each protection measurements available in the controller have to be monitored in advance to avoid any tripping during testing. Any tripping at certain load may incur certain amount of equivalent operating hour. The final result from this project proved that there is an improvement in the operation of fuel gas system. The reduction is mass flow at certain loads are visible. Besides, there is no potential of tripping on GT due to current gas composition.

ABSTRAK

Sistem bahan bakar gas di dalam gas tarbin 13E2 telah direkacipta untuk mengoptimasikan penggunaan bahan api gas dan mengurangkan penghasilan gas nitrogen oksida. Sistem ini terdiri dari kawalan litar tertutup, injap terkawal, injap tertutup, dan alat pembakar. Disebabkan jangka masa operasi yang lama, tahap kecekapan peralatan dan pekakas gas tarbin turut menurun. Di dalam proses pemulihan secara besar-besaran, kesemua pekakas and peralat utama akan ditukar atau dibaiki. Oleh kerana sifat-sifat gas turbin telah berubah, ia tidak lagi sesuai dengan konfigurasi system bahan bakar gas pada waktu itu. Dengan itu, sistem bahan bakar gas perlu di perbetulkan semula. Tujuan utama projek tesis ini adalah untuk menerangkan fungsi and operasi CCGT secara asas. Di dalam sistem ini, terdapat subsistem dipanggil sistem bahan bakar gas. Sistem ini telah di pilih untuk kerja penambahbaikan. Selain itu, tesis ini bertujuan untuk membuktikan bahawa cadangan penambahbaikan mampu mengurangkan penggunaan bahan api gas. Kerja pembetulan konfigurasi tertumpu kepada 3 injap terkawal utama (MBP 41, 42, dan 43). Cara kerja secara khursus telah di tunjukkan dan informasi berkaitan telah di rekod. Selain itu, sistem bahan bakar gas, perkakas yang berkaitan dan cara operasi telah diterangkan secara khursus. Setiap data yang berkaitan dengan keselamatan dan perlindungan yang terdapat di dalam sistem pengawal telah di perhatikan secara langsung. Projek ini membuktikan bahawa penambahbaikan di dalam sistem bahan bakar gas adalah tidak mustahil. Terdapat tahap pengurangan jumlah penggunaan bahan api pada Megawatt tertentu. Selain itu, tiada potensi untuk GT tidak berkemampuan menjalankan tugas di sebabkan komposisi gas semasa.

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LIST OF ABBREVIATIONS

DC	-	Direct current
TNB	-	Tenaga Nasional Berhad
NLDC	-	National Load Dispatch Center
CCPP	-	Combined Cycle Power Plant
GT	-	Gas Turbine
ST	-	Steam Turbine
BOP	-	Balance of Plant
PETRONAS	-	Petroliam Nasional Berhad
HRSG	-	Heat Recovery Steam Generator
VIGV	-	Variable Inlet Guide Vane
TAT	-	Temperature After Turbine
TIT	-	Temperature Inlet Turbine
O&M	-	Operation and Maintenance
HVCB	-	High Voltage Circuit Breaker (275kV)
GCB	-	Generator Circuit Breaker (15.75kV or 19kV)
AGC	-	Automatic Generation Control
CLC	-	Closed Loop Controller
OLC	-	Opened Loop Controller
NO_x	-	Nitric Oxide and Nitrogen Dioxide
PLS	-	Protection Load Shedding
BDQ	-	Bad Data Quality
CCGT	-	Combined Cycle Gas Turbine
EOH	-	Equivalent Operating Hours

LIST OF SYMBOLS

B	-	Magnetic force
F	-	Force
f	-	Frequency, hertz
I	-	Current, ampere
Kg/s	-	kilogram per second
m^3/h	-	meter cube per hour

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Technical approach is a modification of the processes and parameters adjustment of the Combine cycle power plant. The modification of the processes may start from the input (fuel, air, steam etc.) until the power has been delivered to the customer. The settings adjustment shall be carried out along the process as stated before. Both reconfigurations are essential, as it will determine the quantity and quality of final product hence affecting the efficiency of the combine cycle power plant. However certain calibration may be limited due to material and safety constrain.

As far as cost of operating and maintaining are concerned, the technical approach proposed will determine the minimum overall cost yet maximizing the profits. While overall costs reduce, the higher profits may reflex the performance of the operation and maintenance personnel and plant. The minimum operation and maintenance cost also may affect the chances of the new operation and maintenance tender, as it will become a referral.

A suitable technical approach may be implemented base on the current economic situation. The situation may vary from inflation and deflation of economy and planned outage. When the economy is inflated or deflated, each gas turbines and steam turbine shall be equipped with the suitable technical parameters and hence the unique efficiency has been determined. The efficiency may become a guideline during selection for the gas turbine to operate. The highest efficiency is the most favorable to operate as far as profit is concerned. In scheduling the inspection or outage for each unit, the equivalent operating hours (EOH) will become the guidelines. Here the most efficient unit after the new technical approach is applied will be in the schedule first and usually with higher equivalent operating hours interval than others.

In determining the highest capable efficiency, of each unit, the processes and parameters will be adjusted and recalibrated. The recommendation will be based on the virtual model adjustment. The model will be designed base on the actual combine cycle power plant to get the accurate effect during testing.

In a research paper in reference [1], it was introduced the method of investment planning in power plant business. The decision tree is used. The input criteria are no investment, large repair or replace the power plant, and the failure risk cost. At the end of the process, the profits and plants operating rates for each period shall be determined.

The design technical approach will increase the efficiency of the Gas and Steam Turbines. Hence the cost of operate and maintain will reduce. Indirectly the additional profit margin will be given to the Operation and Maintenance (O&M) company. If the cost of the O&M were imposed in the bidding process, it will project a good competitive advantage especially to new O&M company.

In the reference [2-5], it was explained that there are few papers were presented as part of the PowerGen exhibition. It was meant to promote the new design of F class GT. Among the improvements are the new tested compressor design by using 6 sigma methodology, the new single center tie bolt rotor and the new exhaust system. On top of that, it was claimed that the start reliability may achieve from zero speed to base load in 10 minutes. However there was no further information in regards to the combined cycle operation improvement. Nevertheless, in relation to this project, this paper may introduce a room of improvement for the 13E2 design review. Further redesign and test are required to be on par with this new product by Siemens.

In addition to the references above, it was explored on the NO_x emission and reduction for the gas turbine outlet. An equipment was introduced called Lean Head End (LHE) with water and steam injection technique as the testing was carried out at partial and base load. It is proven effective with GT frame 5, 6, and 7.

The writer in the as referred in the Reference [6] also put proposal on optimization by cascading the LNG cycle, Rankine cycle using ammonia-water as a working fluid and Brayton power cycle of power plant. Nevertheless, it was not recorded the actual implementation of such a combination yet.

1.2 Power Business Liberalization

The power market's liberalization throughout the main global economy player's (USA and EU for example) had been triggered in the mid 1990's, hence exerting changes in the power generation and supply businesses of these economies. As a result of this, nowadays, power plant operators had to experience more challenging market environment such as due to strong competition, various uncertainties, and many without long term power purchase agreements. Like a blessings in disguise, the market liberalization also presents new business opportunities such as the utilization of market price fluctuations for operation and maintenance optimization, participation in ancillary service markets, and short term trading.

All of these opportunities can contribute to significantly improve the operating margins. By knowing how to approach these challenges as well as opportunities, an operator can in some cases achieve higher profits and enhance their marketability, without depending too much on long term power purchase agreement which although guarantee security in part of the operators but is still vulnerable towards various uncertainties such as political uncertainties that might review, reconsider or even change completely the accepted policy towards power businesses. Apart from that, these form of dependency of operations on contracts or agreements also restrict power businesses from exploring new opportunities, business ideas and in some extreme uncertain environment will even led operations to go on without profit.

A study was conducted on the liberalization impact on the electricity market as the reference [7] is referred. The focus was toward the coal mining industry. There are 2 scenarios discussed (monopoly and liberation) with the specification of commercialization and privatization, competition, and authorization for the client to buy the power directly from producer.

Furthermore, the more experience gained from operating under liberalized market environment would actually enhances an establishment competitive advantage in order to operate and survive anywhere as the global economic interactions continuously becoming more liberalized with more freedom to invest in new geographical market of varying uncertainties in various terms, thus the supremacy of the fittest eventually dominates globally.

As the reference of [8] is referred, the paper is using Gatecycle program as an assistant for simulation. There are 16 inputs parameters manipulation. They are temperature of GT combustor exit, live steam, HP vaporizer, LP superheater, water LTE and EH, duct burner temperature rise, pressure of LP steam, HP steam, and ST extraction, natural gas ratio, flow rates of compressed air from GT and LP, GT air compressor pressure ratio, efficiencies of heat exchange and steam re-heater. It was proposed to have a mixture of CCGT with integration with steel plant. The air separation unit (ASU) is also part of the system

1.3 Impact of Uncertainty in Power Business

The current economic, social, and political climate in which the electric power industry operates has changed considerably in the last 40 years. Prior to the end of the 1950s, planning for the construction of plant facilities was basically straightforward because it could be assumed that the load would at least double every 10 years. Therefore, past trends provided a relatively simple guide for the future. During the 1960s, generation unit sizes increased and high voltage transmission and interconnections between utilities expanded rapidly to take advantage of the economics of scale. The utility industry economic environment was relatively stable prior to the 1970s. Both inflation and interest rates were predictable, and consequently costs did not change rapidly. Therefore, the uncertainties associated with most aspects of utility finance were minimal, and economic studies could be performed with some degree of certainty.

The oil embargo of the early 1970s disrupted the economic stability of the utility industry. The industry was faced with escalating fuel costs in addition to the possibility of supply interruptions. Furthermore, the United States was experiencing rapid increases in interest rates. These factors represented a reversal of long-standing trends. Public concern for depleting the earth's limited resources along with concern for the environmental impact added to the challenges confronting the utility industry. In addition, the cost of nuclear power was escalating due to new and much rigorous regulations, which made it evident that nuclear power was not going to be a universal supply for the world’s energy needs.

In view of reference [9], this paper introduces a method of energy planning by using energy flow optimization model (EFOM). In this paper, the exploration of multi types of plants and implementation of available saving energy techniques are put into this study. It was shown also that the reduction of emission of the coal based power plant.

The past decade has seen a growing recognition that policies that ignore uncertainty often lead in the long run to unsatisfactory technical, social, and political outcomes. As a result, many large corporations and federal agencies now routinely employ decision analytic techniques that incorporate explicit treatment of uncertainty. Uncertainty is a major issue facing electric utilities in planning and decision-making. Substantial uncertainties exist concerning future load growth, construction times and costs, performance of new resources, and the regulatory and economic environment in which utilities operate. During the past decade, utilities have begun to use a variety of analytical approaches to deal with these uncertainties. These methods include sensitivity, scenario, portfolio, and probabilistic analyses. As typically applied, these methods involve the use of a computer model that simulates utility operations over 20 or 30 years. Fuzzy numbers were also used to model non-statistical uncertainties in engineering economic analysis.

Technology, in businesses aspect can be expressed as all the assets either physical or non-physical (ideas, knowledge, processes, procedures and etc.) that are being applied homogenously together to bring out the deliverable products either physical or non-physical (such as services). In most businesses nowadays, the use or the ability to use technology in their approach towards delivering intended products is one of the key elements towards establishing competitive advantage. A classical example to examine this advantage is in the case of an agricultural business employing machineries in their operations versus an agricultural business that doesn't employ machineries but instead relying much on labor-intensive approach in their operations. In a period of certainty, obviously the former would hold an advantage over the later, but during a period of uncertainty, the elements which made up the advantages might not be tolerated by these uncertainties, for example when there is a an inflation of fuel price, an entity which rely much on machineries would have to decide whether to absorb the spike in operation expenditure or to distribute it to the market to which will definitely lower their competitive advantage significantly brought about by possible market reactions. This example although crude and simplistic in nature, but is sufficient to show just how much the approach of technology can be affected by uncertainties. Therefore, by approaching technology with versatility, uncertainties may be tolerated up to certain degree to which the competitive advantage can still be upheld.

For any profit oriented organizations, whatever they do, whatever decisions the top managements made, whatever approach (technological or technical, financial and etc.) they applied, the final target of all these is no more than to achieve economic objective of these establishments, in the sense of generating optimum wealth for various purpose; expansion, new investments, upgrading, debt pay-up, and so on. So after going through all the series of complexity, the final and most important variable coming out from all these, is merely a simple numeric values of the economic cost or price per base units of products, and from this value the other possibilities are regularly calculated, decided and modified where possible in order to come out with the best possible final value that can potentially tolerate for all other expectations.

There are few simulations have been carried out on the relation with power plant. They are in reference [10]. This paper introduces the simulation and design of fault logic simulation for the HP heater in the 210 MW thermal power plant. The other sample is explored in reference [11].This project modeled the 2 gas turbines and 1 steam turbine configuration of CCGT by using the Matlab software. The data from simulation are compared with real time plant.

1.4 Problem Statement

With respect to what had been discussed previously. It is now obvious that, the power industries are becoming increasingly vulnerable towards various uncertainties, especially economic uncertainties. Economic uncertainties such as during the period of inflation as well as during the period of deflation would certainly exert some effects on the economics of this industry. A simple way to define or mathematically express the economics of an individual power entity is proposed as follow, assuming a fully liberalized energy market:

Previous studies on the optimization of techno-economic relationship of power plants had concluded that total or absolute optimization of this relationship up to this moment is still unsolvable, but then again, certain categorical variables aspects of the power plant can be potentially optimize to tolerate for pressure from external circumstances such as various possibilities of economic uncertainties.

To do this, it is proposed that instead of trying to optimize the whole interrelating variables, it could be easier or potentially reactive if only certain or specific categorical aspect of the whole power plant business be optimized to achieve the desired result. For that matter, certain categorical variables are considered or assumed to be fixed while certain others are dynamic in nature, hence may be predicted to certain value or extent which responds to the dynamics of various probabilities coming from economic uncertainties, and finally certain other or a specific categorical variables be manipulated or optimized to tolerate the dynamics of the responding categorical variables.

This proposed study, predicts that the optimization of internal production process variables or technical aspects of the major process components of combined cycle power plants could potentially tolerate for the dynamic changes of the variables that predictably responds to various probabilities that affects the economics and operation of a power plant.

1.5 Objective of Study

a) To understand the operating concept of combined cycle gas turbine power plant.

b) To studies and understand the detail design, operating concept, and safety operation of fuel gas system.

c) To optimize and validate the new operation concept of fuel gas control valve system.

1.6 Scope of Study

Since the general nature of the key subjects of the proposed topics are well known to be quite broad as well as complex in nature, therefore several scope of studies are put forward as the boundary to which this proposed study would commence.

Apart from that, the technical aspect of the power plants will only be focused on that regarding the process plants (production floor) and its major components as well as its attaching variables, potentials and possibilities that can be related and furthermore be manipulated for the purpose of this study.

The evaluation, discussion and conclusion on the optimization strategies would be drawn on the basis of the real time on the recorded data used for this study and therefore might be subjected to certain fixed limitation of this prescribed methods and tools, hence the forms of which the results, data and information are being processed and tabulated, in contrast with other available tools and methodological approaches that are applicable in this field of studies.

1.7 Thesis structure

In chapter 2, we shall discuss the general principle of operation for the combine cycle power plant. The 13E2 version is focused in this study. The combined cycle plant selected has 3 main sections. They are 3 gas turbines, 3 HRSGs, and 1 steam turbine. Each section will be subdivided into smaller components for further explanation on its function.

In chapter 3, the discussion will be on fuel gas system. It explained the operation concept, the protection limits and the component involved such as the control valve, burners, pilot control valve and the controllers.

Chapter 4 will show the results from the testing and procedure. Chapter 5 is meant for the result and discussion. The next chapter is for conclusion and recommendation. The final topic in this thesis would be the references and appendix.

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