Report of Cooperative Education

The Utility Model for Refinery Plant of PTT Global Chemical Public Company Limited

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ABSTRACT

The aim of this project is to create a utility model for Petroleum Refining Plant for a better prediction of power and steam consumption than an existing Microsoft's Excel program. Petro-SIM^{TM}, process simulation and software of KBC, is a selected tool for this study from its sophisticated and capability to integrate processes, pipelines, and utility systems. The utility system of PTTGC6, a petroleum refinery plant of PTT Global chemical PLC, which consist of three Gas Turbines(GT), two Steam Turbines(ST), three Heat Recovery Steam Generator (HRSG), boiler are included in the model. The results from the simulation are then compared with actual data for evaluation of model performance. The percentage difference of predicted NG consumption at 3 GTs, 3 HRSGs is 0.005, and 3.29, respectively is outperformed the Microsoft's Excel program. The five case studies are performed to find the better option to save energy and utility cost. When decreasing of Low Pressure Superheated Steam consumption for 0.18 tonne/hr, this option could save cost for 669,494 Baht/year. The continuation of the case by decreasing of electrical power consumption for 0.55 MW, the benefit is jumped to 6,236,357 Baht/year. However, the further continuation by decreasing of Lower Pressure Saturated Steam consumption and Medium Pressure Superheated Steam consumption does not have a further benefit. The better option to save cost is decreasing Low Pressure Superheated Steam consumption for 0.18 tonne/hr and electrical power consumption for about 0.55 MW.

Keywords: Petro-SIM Production, Power and Steam consumption, Refinery plant and Utility unit

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NOMENCLATURE

ALP = Above Low Pressure Saturated Steam

BFW = Boiling feed water

GT = Gas turbine

HRSG = Heat Recovery Steam Generator

IPS = Intermediate Pressure Superheated Steam

IPSS = Intermediate Pressure Saturated Steam

LPS = Low Pressure Superheated Steam

LPSS = Low Pressure Saturated Steam

MPS = Medium Pressure Superheated Steam

NG = Natural Gas

ST = Steam turbine

VPS = Very high Pressure Superheated Steam

XPS = Very low Pressure Superheated Steam

CHAPTER I

INTRODUCTION

1.1 Background

PTT Global Chemical Public Company Limited (PTTGC) is the largest integrated petrochemical company in Thailand. PTTGC business covers from upstream, intermediate, and downstream of petrochemical refinery plant. The PTT global chemical refinery plant (PTTGC6) was established in 1996 and is the one of petroleum refinery plant of PTTGC group. PTTGC6 is a full complex refinery which has production capacity of 228,000 barrels per day with one power and steam generator. The complex refinery plant requires large amount and several types of energy sources especially steam to supply heat to its main unit operations such as separation unit, conversion unit and treating units. PTTGC6 generates very high pressure steam(VPS) from Heat Recovery Steam Generator (HRSG) and Boiler and VPS are then used for Steam Turbine(ST). After passing turbine, the steam was turned to Intermediate pressure steam(IPS) and has been used for process unit and converted to medium and low pressure steam(MPS and LPS). Steam will be used several times until its energy is too low for using as energy source. After that it will be recycled back to a process as boiler feed water. The different requirement of steam quality and quantity of each process unit causes the complexness of untility network. Nowaday, Microsoft's Excel program has been used in a plant for balancing demand and supply of power and steam. It is quick and simple software. However, it was created for more than 10 years and has not been updated. In addition, It is a simple program that could not capture the complexness utilites unit. The Petro-SIM^{TM} Refining and Petrochemicals, a process simulation sofware from KBC, are proposed for more accurate results on modeling of utilities unit and distribution of steam usage. The alternative options for cost saving in steam production and usage will be investigated.

1.2 Objectives

1) To create a utility model for PTTGC Refining Plant for a better prediction of power and steam consumption than an existing Microsoft's Excel program.

2) To find the better option to save energy and utility cost.

1.3 Scopes of Work

1) This work will focus on simulation of utilities unit of PTTGC6 refinery plant which including main units such as heat recovery steam generator, gas turbines and steam turbines, and distribution of steam pipeline.

2) The input and output for model investigation will be extracted from 1-year of process data (October 2016-September 2017).

1.4 Expected Outputs

1) PTTGC will have the utilities model that has a better performance and more accurate that an existing Microsoft Excel program which could be used to manage steam production and usage.

2) Student will gain experience on building utilities model in a complex utilities network of a refinery plant using process simulation software and data management program.

CHAPTER II

THEORY AND LITERATURE REVIEW

The utility system is a supporting unit to supply energy source especially steam to other process unit in petroleum refinery plant. Modeling of utility system is necessary to manage production and consumption of steam in a plant. Chapter II will provide background information necessary for building utility model including steam generation, steam distribution, process simulation and literature review.

2.1 Steam generation [1]

The objective of generating steam from boiling of water is to provide a flexible and safe means of energy source or convert to useful form such as electrical generation. Steam is generated when supply enough energy from fuel gas or other sources to change phase from liquid to vapor. However, boiler feed water must be treated to prevent scaling, corrosion, foaming, and priming that may occur in boiler. Steam could be used for many applications such heating/sterilization, drive steam turbine and equipment such as compressor and pump, cleaning, humidification, and etc. Steam generators and heat recovery boilers are vital units for power and chemical industries. There are many issues that need to be concern for boiler such efficiency, environmental impact from wasted gas. The steam generation system in a refinery plant consists of deaerator, pump and boilers as shown in Figure 2.1

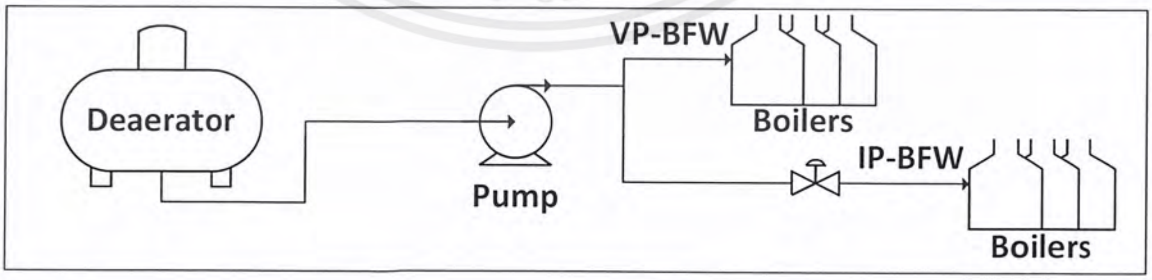


Figure 2.1 Overview of refinery's steam production process

2.1.1 Deaerator [2]

Deaeration is the mechanical unit to removal dissolved gases from the boiler feed water and simultaneously chemical removal. A deaerator is commonly equipment that is widely used for the removal of oxygen and other dissolved gases from the boiling feed water to steam-generating boilers. Dissolved oxygen in boiling feed water will cause serious corrosion damage in steam systems. In addition, dissolved carbon dioxide in water could form carbonic acid that causes further corrosion. Most deaerators are designed to remove oxygen concentration in water to below 7 ppb and eliminating carbon dioxide. Schematic diagram of typical aerator is shown in Figure 2.2.

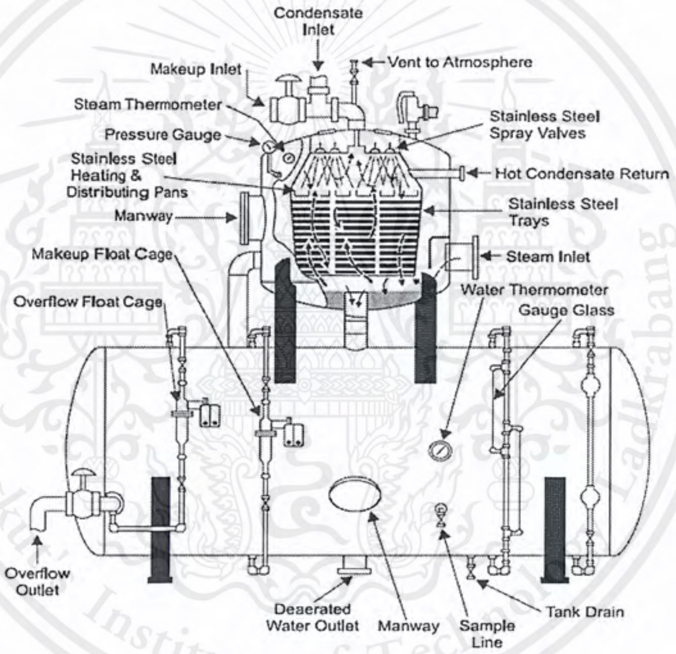


Figure 2.2 Cross section of typical Deaerator

The incoming boiling feed water is pumped from the condensate pumps through condensate inlet. The water is sprayed in a fine mist and mix with water from Hot Condensate Return. The water is then passed over a set of trays that separates the water into thin sheets from which the gas can easily escape. The gases are then vented out of the deaerator to the atmosphere. The deaerated water is collected in a bottom tank.

There are two basic types of deaerators, i.e, the tray-type or the cascade-type which includes a vertical domed deaeration section mounted on top of a horizontal cylindrical vessel which serves as the deaerated boiling feed water storage tank and the spray-type which consists only of a horizontal (or vertical) cylindrical vessel which serves as both the deaeration section and the boiling feed water storage tank. There are several corrosion types that can occurs in boiler.

1. Pitting

Pitting is a form of corrosion that leads to the creation of small holes in the economizer and boiler due to oxygen dissolved in deaerated feed water is more than 7 ppb. A typical area of oxygen pitting is shown in Figure 2.3.

Figure 2.3 Oxygen pitting of economizer feed water inlet

2. Iron compound formation

Iron compound generation results from oxygen dissolved in deaerated feed water as same as pitting. Iron goes into solution according to the following formula:

$$Fe + 2H_2O \rightarrow Fe(OH)_2 + H_2 \qquad (2.1)$$

The ferrous hydrate ($Fe(OH)_2$) which is formed is alkaline and will raise the pH of the water. However, if oxygen is present in water, it immediately oxidizes the ferrous hydrate forming ferric hydrate ($Fe(OH)_3$) which is precipitates.

3. Fouling

Fouling consist of deposition of solids, primarily iron which can increase pressure drop, reduce heat transfer and also reduce performance. Chemical agents is used to scavenge residual oxygen called “Oxygen Scavenger” and typically chemical agents are sodium sulfite for low pressure, hydrazine for high pressure and hydrazine can reacts with oxygen within one minute nevertheless hydrazine as known as carcinogen.

2.1.2 Pump [3]

A pump is a mechanical device used to moving a liquid that adds energy to a fluid to increase its flow rate and static pressure. Pump displaces a volume by physical or mechanical action. The most common types of liquids pumped in upstream industries are crude oil, condensate, lube oils, glycols, amines, and water. Each fluid has different physical properties that must be taken into consideration when sizing and selecting a pump. The most important physical properties are specific gravity, viscosity, vapor pressure, solids content, and lubricity. The operating characteristics are important as density of liquid, pressure differences are usually considerable and heavy construction is needed. Figure 2.4 is shown a typical pump application.

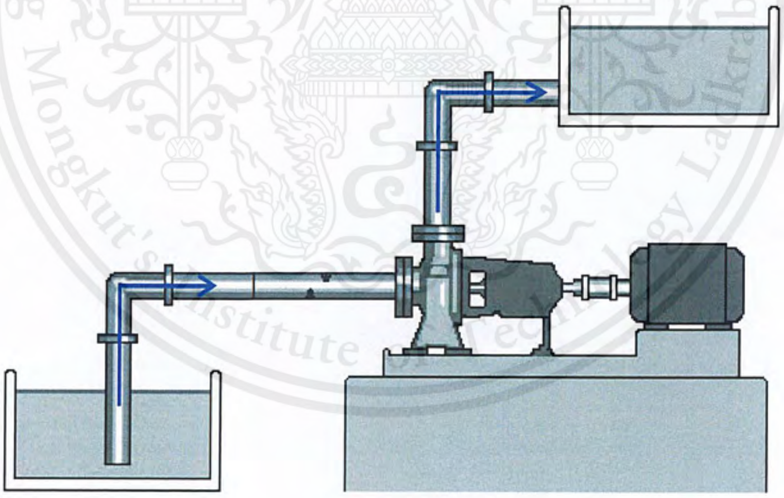


Figure 2.4 Pump flow system

Water in tank is draw through pump that is installed in pipeline and discharge a constant volumetric flowrate at the exit of pipeline. The almost widely used pump is centrifugal pump which centrifugal action increases the mechanical energy of liquid and Figure 2.5

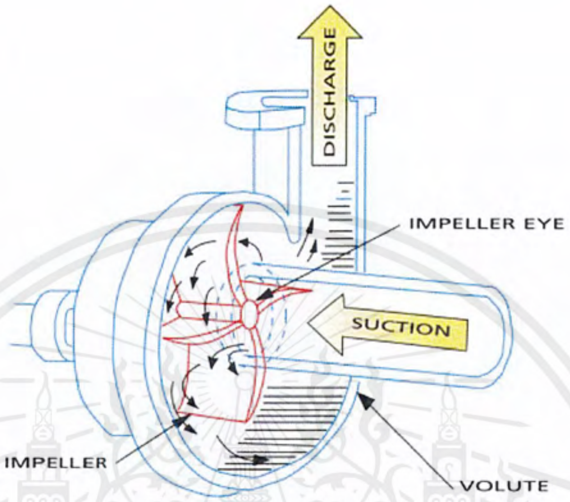


Figure 2.5 Centrifugal pump working

The centrifugal pump is usually driven by a direct-connected motor at constant speed which commonly at 1750 r/min furthermore the direct-connected motor are regularly engines, electrical motor, steam and gas with turbine.

2.1.3 Steam generator [4]

A steam generator also known as boiler is a heart of steam generation. This is the machine that transfers the fuel energy from the combustion system to boiling feed water in a pressure vessel to make steam. The alternative energy source for boiler is heat recovery as called “Heat recovery boilers” which recover waste heat from other process that heat remaining or by product.

Heat recovery boilers implies waste heat recovery boilers or heat recovery steam generators (HRSGs), the basic objectives of the heat recovery steam generators is to transfer heat from the exhaust gases of gas-turbine or internal combustion engine processes to the boiling feed water in order to produce a steam. The most common heat recovery boiler is a heat recovery boiler with gas turbine. The heat recovery boiler with gas turbine or Gas Turbine HRSGs consists of major components such as economizer, evaporator, and superheater. Economizer is equipment that heat boiling feed water to close to saturation point. Evaporator transforms heated boiling feed water from the economizer to steam and separate the steam from water in a drum steam. Superheater and reheater heat steam to beyond saturation point or superheated point. Stack releases exhaust gas from HRSG to the atmosphere. However, the exhaust gas from gas-turbine or internal combustion engine processes is not enough to produce steam. It required a supplementary fuel is mixed with exhaust gases in burners. Figure 2.6 is shown schematic diagram of HRSG with flow path of exhaust gas (red line) and water/steam (blue line). Typically, very high pressure steam(VPS) is produced from HRSG.

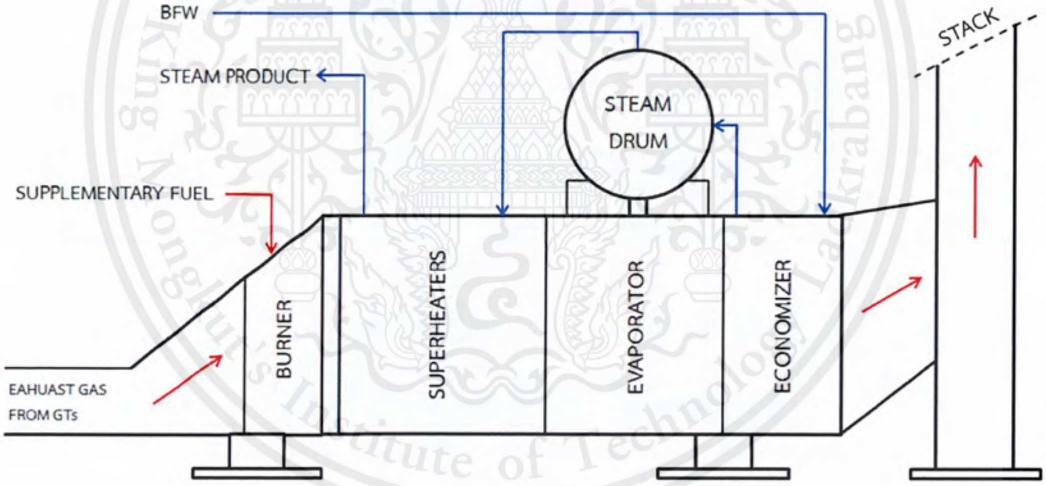


Figure 2.6 Flow path in heat recovery steam generator

2.2 Steam distribution [5]

The distribution system of steam consists of valves, fittings, piping, and connections suitable for the pressure of the steam transported. Steam leaves the boilers at the highest pressure are required by the process units or electrical generation. The steam pressure is then reduced in turbines to level that can drive process pumps and compressors. Most steam used in the refinery is condensed to water in various types of heat exchangers. The condensate is reused as boiling feed water or discharged to wastewater treatment. When steam is also used to drive steam turbine generators to produce electricity, the steam must be produced at much higher pressure than required for process steam. The overview of steam utility network in a refinery plant is shown in Figure 2.7. There are several of steam types including;

- Very high pressure superheated steam (VPS)
- Intermediate pressure superheated steam (IPS)
- Intermediate pressure saturated steam (IPSS)
- Medium pressure superheated steam (MPS)
- Above low pressure saturated steam (ALP)
- Low pressure superheated steam (LPS)
- Low pressure saturated steam (LPSS)
- Very low pressure superheated steam (XPS)

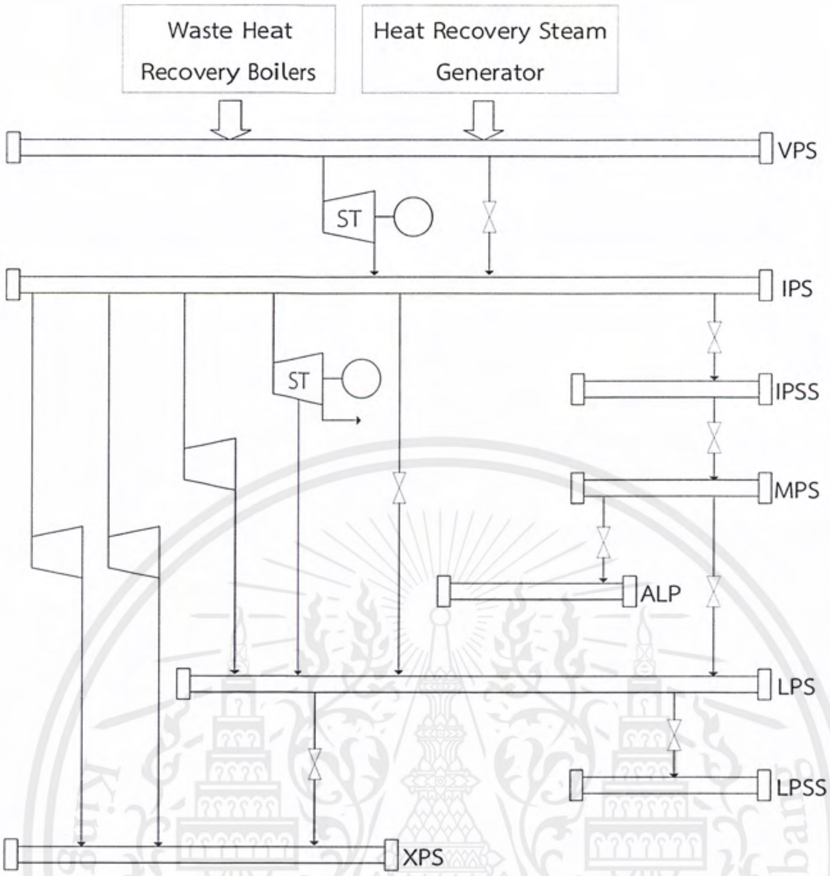


Figure 2.7 Overview of steam utility network

The lowest steam level or XPS is recycling to treatment unit. Table 2.1 is shown pressure and temperature of each steam type. Each level of steam yields different energy quantity depends on pressure and temperature. Superheated steam is mainly used in propulsion or drive applications to generate electrical power such as steam turbines, is not typically used for heat transfer applications. Saturated steam has many properties that make it an excellent heat source.

Table 2.1 Properties of each steam level.

Steam level	Pressure (barg)	Temperature (degC)
VPS	120	520
IPS	42	380
IPSS	41.5	254
MPS	7	170
ALP	3.8	150.4
LPS	3.5	190
LPSS	3.5	148
XPS	1.8	140

2.3 Process simulation [6]

Simulation is a fundamental activity in Process Engineering. The following definition captures its essential features (Thom6, 1993)"

> *"Simulation is a process of designing an operational model of a system and conducting experiments with this model for the purpose either of understanding the behaviour of the system or of evaluating alternative strategies for the development or operation of the system. It has to be able to reproduce selected aspects of the behaviour of the system modelled to an accepted degree of accuracy."*

However, a simulation model could not be used to present a real process without any evaluation with real data. The correct Input and appropriated thermodynamics data for process simulation are also key parameters for the modeling. Using inappropriate thermodynamic data may cause a failure in computer-aided design. The process simulation programs that are widely used are;

- AspenTech

Aspen Plus, is the software of AspecTech. It allows us to predict the behavior of a process using basic engineering relationships. As taught in process modeling and simulation course that we describe a given physical process. And the physical process is specified or described by an equivalent mathematical portray. In general, writing such equations stems from

- balance equations of extensive thermodynamic properties, such as mass, mole, and energy;
- thermodynamic relationships for reacting and non-reacting medium, such as phase and chemical equilibrium;
- rate correlations for momentum, heat, and mass transfer;
- reaction stoichiometry and kinetic data;
- physical constraints imposed on the process

Aspen Plus can define the process flowsheet as unit operation and process stream.

- KBC Advanced Technologies [7]

Petro-SIM is the software of KBC Advanced Technologies, a leading simulation engine and optimization platform for driving excellence in location efficiency and organizational performance. At the part of Petro-SIM's technology, simulation models generate dependable results in an intelligent, user-friendly environment. Petro-SIM is a simulation platform for refining and petrochemicals upstream and downstream.

Petro-SIM is fully developed, making it an effective predictive and analytical tool. It closes the loop between monitoring and planning so that it can be compared real-time to actual and simulations. Key features of Petro-SIM include:

- Addresses each phase of the lifecycle of a facility
- Integrates processes, pipelines and utility systems within a single environment, including highly detailed sizing and rating models for unit operations
- Built to work in real-time, for monitoring unit health and profitability
- Allows superior collaboration and version control, and the ability to build in your own design standards and checks
- Contains all the infrastructure to connect and manage messy real-world data, including historian connections, data validation and reconciliation

Supports data and model analytics, with all simulation calculations stored in a database for historical analysis and data mining.

2.4 Literature review

Jose Bird et al.[8]. This paper studied optimization of Refining Crude Distillation Process Unit using Process Simulation and Statistical Modeling Methods. This paper used process simulation to evaluate the crude distillation unit performance and a set of 60 simulation cases were defined which has a lot of data. They reviewed process simulation by using Petro-SIM$^{\text{TM}}$ Process Simulation Software that its user friendly Microsoft's Excel software spreadsheet interface and easy to manage a lot of data. That is provides the capability to run a multiple cases.

Bálint Silhavy et al.[9] This paper revealed the linking simulator with Microsoft's Excel program, which It combines the strengths of both software tools. Microsoft's Excel can reset input data and supervises operations of the process simulator. As the storage capacity of the MS Excel is practically unlimited, it is an ideal co-operating partner for the process simulator. VBA (Visual Basic for Applications) is one of advantages. The mutual connection between process simulator and Microsoft's Excel is created by interface software. The input data for every simulation were always set in Microsoft's Excel and transferred to process simulator.

CHAPTER III

METHODOLOGY

From two objectives of this project, first is to create a utility model for PTTGC Refining Plant for a better prediction of power and steam consumption than an existing Microsoft's Excel program and to find the better option to save energy and utility cost. The process simulator program Petro-SIM (PS) of a KBC Advanced Technologies plc was used as a tool for create utility model. Workflow diagram for create the model is shown in Figure.3.1 The first step is data collection, follow by data selection, modeling, validation & Tuning the model, and find options for improvement, respectively.

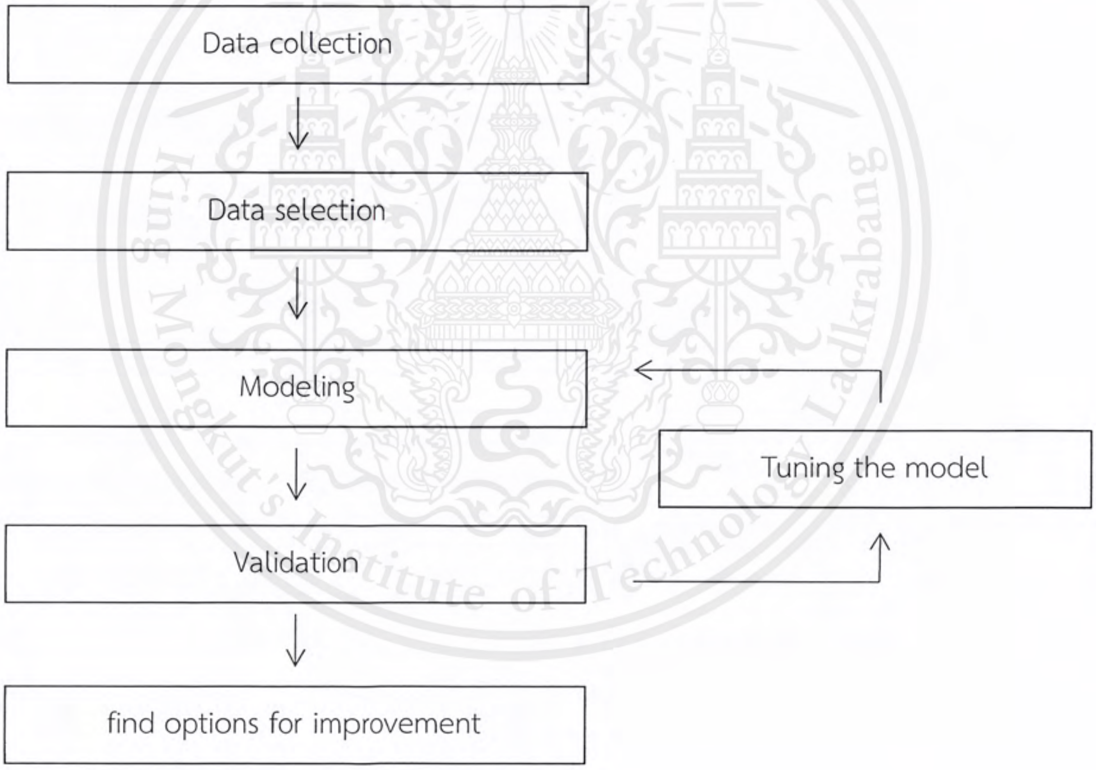


Figure 3.1 Workflow Diagram for the study

3.1 Data collection

Data collection is the process of gathering information from a various sources to get required data to meet the objectives. The specification of major equipments, process data, energy and steam consumption data are collected. The example of required data is shown in Table 3.1.

Table 3.1 Example of required data

Equipment	Parameter
Deaerator	Flowrate Operating pressure Preheat temperature
Pump	Flowrate Discharge pressure Mechanical Power (Efficiency)
Gas turbine	Generator efficiency Power generation Gas turbine model Pressure loss
Boiler	Flowrate (material & heat) Outlet Temperature Pressure drop
Steam turbine	Generator efficiency Power generation

These are input data for utility unit, all equipment that related the energy and steam consumption. The data was collected for one year peroid from August 2016-July 2017.

3.2 Data selection

Data from previous step are screened for abnormality using statistic tools. The data during normal operation were selected as input and model validation.

3.3 Modeling

Petro-SIM Production Software by KBC was be used in this project. Picture of tools bar of Petro-SIM Production Software as shown in Figure 3.2. First of simulation is create each process in sub-flowsheet which equipment is in the operations tool. Then input the information that through data selection step. Connected all sub-flowsheet together to complete process.

Figure 3.2 Tools bar of Petro-SIM Production Software

Equipment icon can be set in shortcut tab which operations consist of general, separation, logical and refinining tool as shown in Figure 3.3.

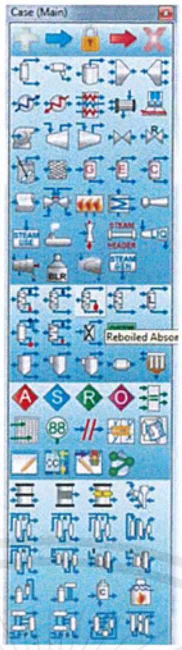
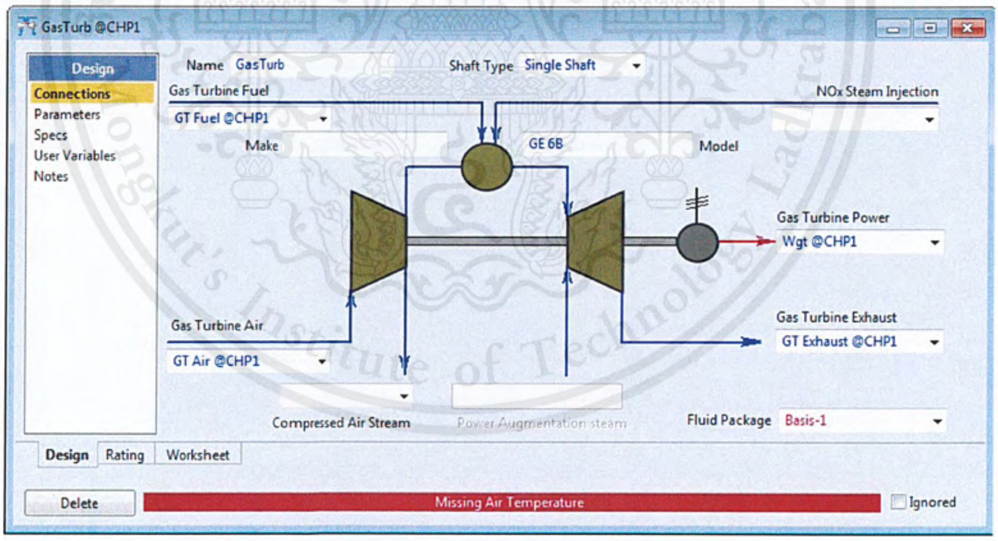


Figure 3.3 Shortcut icon of operations tool

The example of equipment information that input is shown in Figure 3.4, 3.5 and 3.6. The some equipment require size and loading for accurate simulation.



Name GasTurb

Shaft Type Single Shaft

Gas Turbine Fuel GT Fuel @CHP1

NOx Steam Injection

Make GE 6B Model

Gas Turbine Power Wgt @CHP1

Gas Turbine Exhaust GT Exhaust @CHP1

Gas Turbine Air GT Air @CHP1

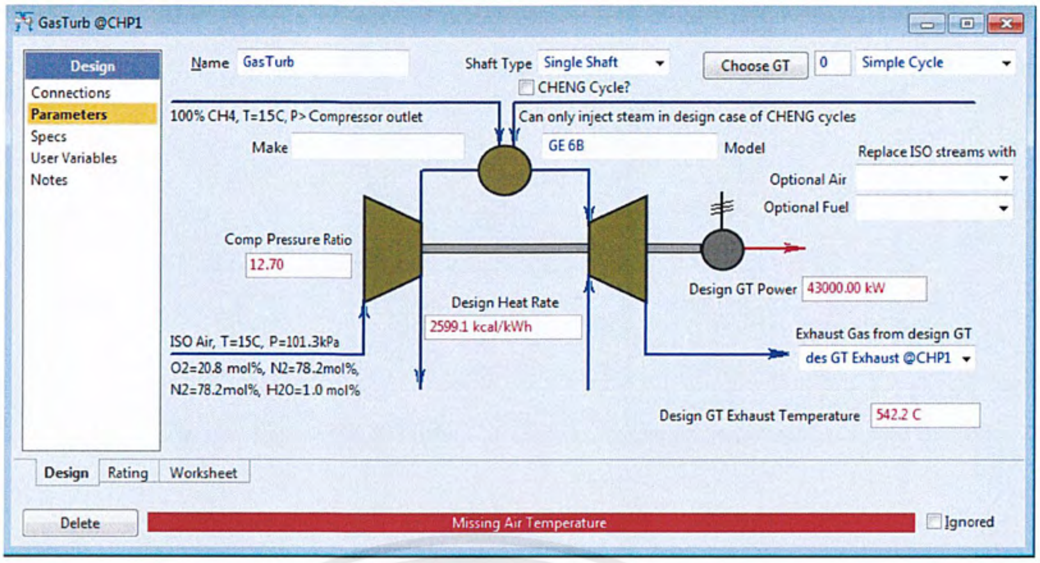
Compressed Air Stream

Power Augmentation steam

Fluid Package Basis-1

Missing Air Temperature

Figure 3.4 Example of gas turbine design in connections



Name GasTurb

Shaft Type Single Shaft

0 Simple Cycle

☐ CHENG Cycle?

100% CH4, T=15C, P> Compressor outlet

Can only inject steam in design case of CHENG cycles

Make

GE 6B Model

Replace ISO streams with

Optional Air

Optional Fuel

Comp Pressure Ratio 12.70

Design Heat Rate 2599.1 kcal/kWh

Design GT Power 43000.00 kW

ISO Air, T=15C, P=101.3kPa
O2=20.8 mol%, N2=78.2mol%,
N2=78.2mol%, H2O=1.0 mol%

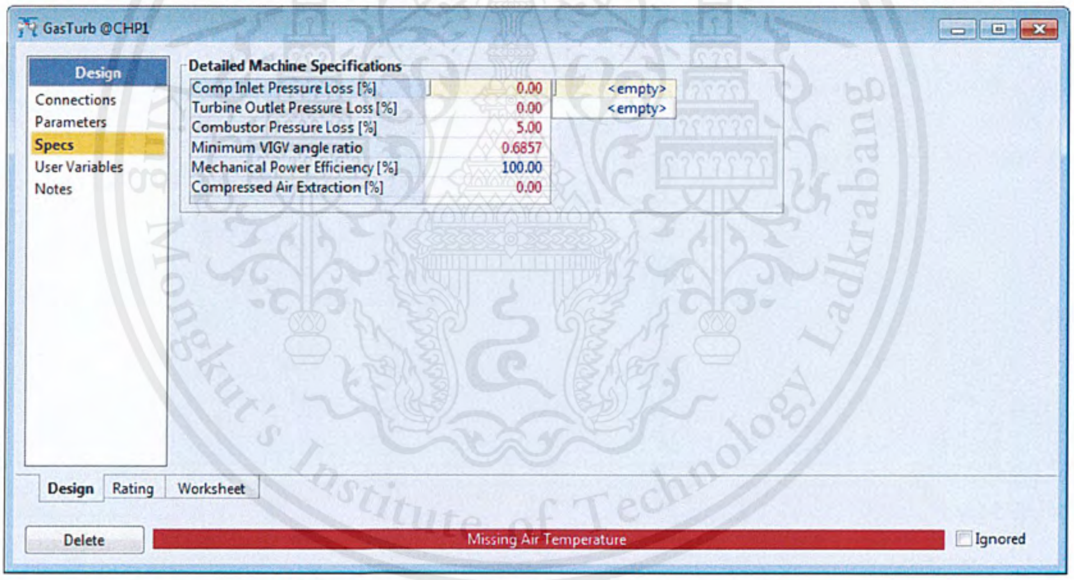
Exhaust Gas from design GT des GT Exhaust @CHP1

Design GT Exhaust Temperature 542.2 C

Missing Air Temperature

☐ Ignored

Figure 3.5 Example of gas turbine design in parameters



Detailed Machine Specifications

Comp Inlet Pressure Loss [%]	0.00	<empty>
Turbine Outlet Pressure Loss [%]	0.00	<empty>
Combustor Pressure Loss [%]	5.00	
Minimum VIGV angle ratio	0.6857	
Mechanical Power Efficiency [%]	100.00	
Compressed Air Extraction [%]	0.00	

Missing Air Temperature

☐ Ignored

Figure 3.6 Example of gas turbine design in specs

3.4 Validation and Tuning

This step is a step to correct erros of the model by using observation data from process equipment for comparison with modelled data. If the different between observation and modelled data is exceed the acceptable range. The model parameter will be tunned until these two data are closed. The flowchart of validation and tuning method is shown in Figure 3.7

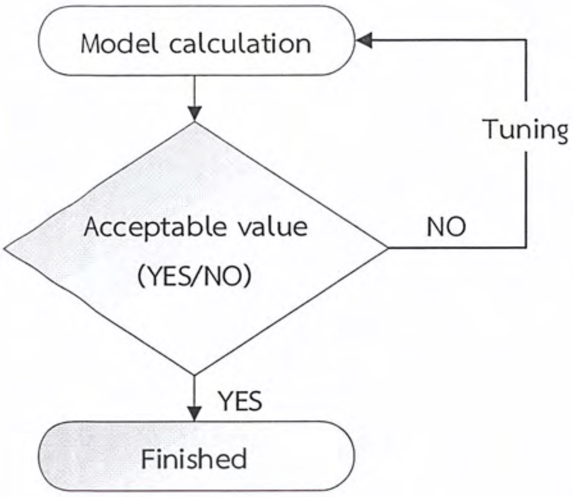


Figure 3.7 Flowchart of validation and tuning method

3.5 find options for improvement

To find options for utilities process improvement, five case studies were performed. The detailed descsription of these five cases is shown in Table 3.2. The target of those cases was to find the better option to save energy and utility cost.

Table 3.2 Case studies for saving cost options

Case study	Description
Case 1	Base case + decreasing 0.18 tonne/hour of LPS steam consumption
Case 2	Case 1 + decreasing 0.05 MW of electrical power consumption
Case 3	Case 1 + decreasing 0.55 MW of electrical power consumption
Case 4	Case 3 + decreasing 0.25 tonne/hour of LPSS steam consumption
Case 5	Case 4 + decreasing 0.1 tonne/hour of MPS steam consumption

CHAPTER IV

RESULTS AND DISCUSSION

This chapter describes the modeled results by using Petro-SIM Production Software compare with observation data and Microsoft's Excel calculation, and options for improvement.

4.1 Modeling results and validation of model

The results from utility model that built from Petro-SIM Production Software for based case are shown in Table 4.1 compare with actual data and excel data. In this table, there are natural gas (NG) consumption at three gas turbines (GTs) and three heat recovery steam generators (HRSGs), electrical power production at 3GTs and each steam turbines (ST) and total consumption of each steam level.

Table 4.1 Natural gas consumption and Steam consumption for base case

Date selection: March 15, 2017		ACTUAL	MODEL	EXCEL
NG consumption at 3GTs	MMBTU/yr	3.8238×10^6	3.8239×10^6	3.8430×10^6
	MBaht/yr	1,114.18	1,114.23	1,119.79
NG consumption at 3HRSGs	MMBTU/yr	1.7158×10^6	1.7732×10^6	1.8336×10^6
	MBaht/yr	429.96	444.34	459.5
GT-3301/2/3	MW	40.37	40.59	41.96
ST-3304	MW	10.14	10.15	10.442
ST-3305	MW	2.91	3.05	4.36
Total Electrical Power	MW	53.42	53.79	56.76
Steam consumption				
VPS	tonne/hr	225.8	225.8	226.28
IPS	tonne/hr	225.8	225.8	226.28
IPSS	tonne/hr	42.6	42.6	38.73
MPS	tonne/hr	21.89	21.89	22.27
ALP	tonne/hr	1.15	1.15	1.15
LPS	tonne/hr	89.53	89.53	105.92
LPSS	tonne/hr	32.48	32.48	26.55
XPS	tonne/hr	38.01	38.01	44.13

From the results, modeled NG consumption at 3GTs is closer to actual value than the results of excel. The Petro-SIM Production Software has a built-in gas turbine model that more sophisticated than the simple calculation in excel. Natural gas consumption at 3HRSGs yields the similar results. However, percentage differences of NG consumption at 3HRSGs between actual and model data are greater as shown in Table 4.2

Table 4.2 Percentage differences of natural gas consumption

Type	Actual value	Model value	Percentage difference
NG consumption at 3GTs	3.8238×10^6	3.8239×10^6	0.0052%
NG consumption at 3HRSGs	1.7158×10^6	1.7732×10^6	3.2903%

When comparing electrical power production of gas turbine and steam turbine, the results are similar to NG consumption. However, when look at steam consumption in each level. The excel data are far from actual value than the other data. The reason might occur because excel calculation was built several years ago and has not been updated.

4.2 Case study results

In this study, five case studies have been performed by decreasing steam and electrical power consumption to find options to optimize steam usage and maximize profit.

1) **Case 1: Decreasing 0.18 tonne/hour of LPS steam consumption from base case**

Case 1 performed an option by decreasing LPS steam consumption about 0.18 tonne/hr, simulation results show that NG consumption and electrical power at 3GTs are slightly increased. While the rest of data are slightly unchanged or decrease as shown in Table 4.3.

Table 4.3 Natural gas and steam consumption in case 1

Date selection: March 15, 2017		Model base case	MODEL case 1
NG consumption at 3GTs	MMBTU/yr	3.8239×10^6	3.8256×10^6
	MBaht/yr	1,114.23	1,114.71
NG consumption at 3HRSGs	MMBTU/yr	1.7732×10^6	1.7686×10^6
	MBaht/yr	444.34	443.20
GT-3301/2/3	MW	40.595	40.615
ST-3304	MW	10.15	10.14
ST-3305	MW	3.05	3.04
Total Electrical Power	MW	53.795	53.795
Steam consumption			
VPS	tonne/hr	225.82	225.64
IPS	tonne/hr	225.82	225.64
IPSS	tonne/hr	42.60	42.60
MPS	tonne/hr	21.89	21.89
ALP	tonne/hr	1.15	1.15
LPS	tonne/hr	89.53	89.35
LPSS	tonne/hr	32.48	32.48
XPS	tonne/hr	38.01	38.01

When compare the change of NG cost of Gas Turbines and HRSGs with base case, case 1 could save money for about 669,494 Baht/year. The summary of cost saving is shown in Table 4.4

Table 4.4 Summary of cost saving for case 1

Natural gas cost change	Baht/year
Gas turbines	-477,494
Heat Recovery Steam Generators	1,146,989
Total saving cost	669,494

2) **Case 2 was performed by decreasing electrical power consumption by 0.05 MW on top of case 1.**

Case 2 is a case that decreasing electrical power consumption about 0.05 MW on top of case 1 and the results is shown in Table 4.5. For this case, steam consumption is not changed. However, decreasing of Electrical power at 3GTs has influenced on NG consumption at 3GTs and 3HRSGS. The results show that NG consumption at 3GTS is decreased while NG consumption at 3HRSGs is increased.

Table 4.5 Natural gas and steam consumption in case 2

Date selection: March 15, 2017		**Model base case**	**Model Case 1**	**Model case 2**
NG consumption at 3GTs	MMBTU/yr	3.8239×10^6	3.8256×10^6	3.8216×10^6
	MBaht/yr	1,114.23	1,114.71	1113.56
NG consumption at 3HRSGs	MMBTU/yr	1.7732×10^6	1.7686×10^6	1.7701×10^6
	MBaht/yr	444.34	443.20	443.58
GT-3301/2/3	MW	40.595	40.615	40.565
ST-3304	MW	10.15	10.14	10.14
ST-3305	MW	3.05	3.04	3.04
Total Electrical Power	MW	53.795	53.795	53.745

Table 4.5 Natural gas and steam consumption in case 2 (Cont.)

Date selection: March 15, 2017		Model base case	Model Case 1	Model case 2
Steam consumption				
VPS	tonne/hr	225.82	225.64	225.64
IPS	tonne/hr	225.82	225.64	225.64
IPSS	tonne/hr	42.60	42.60	42.60
MPS	tonne/hr	21.89	21.89	21.89
ALP	tonne/hr	1.15	1.15	1.15
LPS	tonne/hr	89.53	89.35	89.35
LPSS	tonne/hr	32.48	32.48	32.48
XPS	tonne/hr	38.01	38.01	38.01

When compare the change of NG cost of Gas Turbines and HRSGs with case 1, case 2 could further save money for about 770,243 Baht/year. The additional cost saving of case 2 from case 1 is shown in Table 4.6.

Table 4.6 The additional cost saving of case 2 from case 1

Natural gas cost change	Baht/year
Gas turbines	1,152,572
Heat Recovery Steam Generators	-382,330
Total saving cost	770,243

3) **Case 3 was performed by decreasing electrical power consumption by 0.55 MW on top of case 1.**

Case 3 is a case that similar to case 2 but further decreasing of electrical power consumption by 0.55 MW. Results of case 3 is go to the same direction as case 2 with larger amount of NG consumption decreasing for 3GTs and increasing for 3 HRSGs.

Table 4.7 Natural gas and steam consumption in case 3

Date selection: March 15, 2017		Model base case	Model Case 2	Model case 3
NG consumption at 3GTs	MMBTU/yr	3.8239×10^{6}	3.8216×10^{6}	3.7876×10^{6}
	MBaht/yr	1,114.23	1,113.56	1103.65
NG consumption at 3HRSGs	MMBTU/yr	1.7732×10^{6}	1.7701×10^{6}	1.7847×10^{6}
	MBaht/yr	444.34	443.58	447.24
GT-3301/2/3	MW	40.595	40.565	40.065
ST-3304	MW	10.15	10.14	10.14
ST-3305	MW	3.05	3.04	3.04
Total Electrical Power	MW	53.795	53.745	53.245
Steam consumption				
VPS	tonne/hr	225.82	225.64	225.64
IPS	tonne/hr	225.82	225.64	225.64
IPSS	tonne/hr	42.60	42.60	42.60
MPS	tonne/hr	21.89	21.89	21.89
ALP	tonne/hr	1.15	1.15	1.15
LPS	tonne/hr	89.53	89.35	89.35
LPSS	tonne/hr	32.48	32.48	32.48
XPS	tonne/hr	38.01	38.01	38.01

For economically, case 3 could save further money from case 2. This case could save 6,236,357 baht/year more from case 2 as shown in Table 4.8

Table 4.8 The additional cost saving of case 3 from case 2

Natural gas cost change	Baht/year
Gas turbines	9,903,889
Heat Recovery Steam Generators	-3,667,532
Total saving cost	6,236,357

4) **Case 4 is a case on top of case 3 by further decreasing Low Pressure Saturated Steam (LPSS) consumption 0.25 tonne/hour.**

Case 4 that is a case on top of case 3 by further decreasing LPSS steam consumption about 0.25 tonne/hr, NG consumption at 3GTS is increased while NG consumption at 3HRSGs is decreased when compare with results from case 3. Electrical power at 3GTs are slightly increased but decreased for 2 STs. The steam consumption in each level are either unchanged or decreased as shown in Table 4.9.

Table 4.9 Natural gas and steam consumption in case 4

Date selection: March 15, 2017		Model base case	Model Case 3	Model case 4
NG consumption at 3GTs	MMBTU/yr	3.8239×10^{6}	3.7876×10^{6}	3.7908×10^{6}
	MBaht/yr	1,114.23	1103.65	1104.57
NG consumption at 3HRSGs	MMBTU/yr	1.7732×10^{6}	1.7847×10^{6}	1.7792×10^{6}
	MBaht/yr	444.34	447.24	445.86
GT-3301/2/3	MW	40.595	40.065	40.088
ST-3304	MW	10.15	10.14	10.13
ST-3305	MW	3.05	3.04	3.027
Total Electrical Power	MW	53.795	53.245	53.245

Table 4.9 Natural gas and steam consumption in case 4 (Cont.)

Date selection: March 15, 2017		Model base case	Model Case 3	Model case 4
Steam consumption				
VPS	tonne/hr	225.82	225.64	225.26
IPS	tonne/hr	225.82	225.64	225.26
IPSS	tonne/hr	42.60	42.60	42.60
MPS	tonne/hr	21.89	21.89	21.89
ALP	tonne/hr	1.15	1.15	1.15
LPS	tonne/hr	89.53	89.35	89.10
LPSS	tonne/hr	32.48	32.48	32.23
XPS	tonne/hr	38.01	38.01	38.01

Economically, case 4 could further save 458,067 baht/year from case 3 as shown in Table 4.10

Table 4.10 The additional cost saving of case 4 from case 3

Natural gas cost change	Baht/year
Gas turbines	-924,477
Heat Recovery Steam Generators	1,382,544
Total saving cost	458,067

5) **Case 5 is a case on top of case 4 by further decreasing Medium Pressure Superheated Steam (MPS) consumption 0.1 tonne/hour**

Case 5 was performed by decreasing MPS Steam consumption and letdown or by product to LPS which the results of this case are shown in Table 4.11. NG consumption and electrical power at 3GTs are slightly increased while NG consumption at 3HRSG and electrical power at steam turbines are decreased. And the rest of data are slightly unchanged or decreased.

Table 4.11 Natural gas and steam consumption in case 5

Date selection: March 15, 2017		Model base case	Model Case 4	Model case 5
NG consumption at 3GTs	MMBTU/yr	3.8239×10^6	3.7908×10^6	3.7920×10^6
	MBaht/yr	1,114.23	1104.57	1104.93
NG consumption at 3HRSGs	MMBTU/yr	1.7732×10^6	1.7792×10^6	1.7766×10^6
	MBaht/yr	444.34	445.86	445.21
GT-3301/2/3	MW	40.595	40.088	40.096
ST-3304	MW	10.15	10.13	10.127
ST-3305	MW	3.05	3.027	3.022
Total Electrical Power	MW	53.795	53.245	53.245
Steam consumption				
VPS	tonne/hr	225.82	225.26	225.16
IPS	tonne/hr	225.82	225.26	225.16
IPSS	tonne/hr	42.60	42.60	42.60
MPS	tonne/hr	21.89	21.89	21.89
ALP	tonne/hr	1.15	1.15	1.15
LPS	tonne/hr	89.53	89.10	89.10
LPSS	tonne/hr	32.48	32.23	32.23
XPS	tonne/hr	38.01	38.01	38.01

Economically, case 5 could further save 297,372 baht/year from case 4 as shown in Table 4.12

Table 4.12 Saving cost of case 5 from case 4

Natural gas cost change	Baht/year
Gas turbines	-354,004
Heat Recovery Steam Generators	651,376
Additional saving cost	297,372

The summarization of total cost saving of case 1-5 from base case is shown in Table 4.13.

Table 4.13 Total cost saving of case 1-5

Natural gas cost change	Case 1	Case 2	Case 3	Case 4	Case 5
Gas turbines	-477,494	675,078	10,578,967	9,656,909	9,302,904
Heat Recovery Steam Generators	1,146,989	764,659	-2,902,873	-1,522,238	-870,862
Total saving cost	669,494	1,439,737	7,676,094	8,134,671	8,432,043

4.3 Data management results

From Linked between Petro-SIM's utility model and PI system^{TM} by Microsoft's Excel program, the required data in model can adjust by Microsoft's Excel spreadsheet that connected PI system^{TM}. This reason can easy manage data in utility model and utility model is run quickly.

CHAPTER V

CONCLUSION

5.1 Conclusions

In this project, process simulation software was used as a tool to generate utility model for calculation of energy and steam consumption in a complex Petroleum Refinery plant. The propose is to find a better model to substitute the existing Microsoft's Excel program that has moderate performance and obtain an option to optimize energy and steam consumption for cost saving.

5.1.1 Modeling results and validation of model

The utility model for Petroleum Refinery plant that created by Petro-SIM, a process simulation software has a better performance that the existing model that was created by Microsoft's Excel program. The sophisticated of the Petro-Sim that options for Gas turbine type, better Thermodynamics package results in percentage difference of natural gas consumption between actual and model only at 0.0052% and 3.2903% of gas turbine and heat recovery steam generation, respectively.

5.1.2 Case studies results

Five case studies, have been performed to find a better option to optimize energy and steam consumption for cost saving.

- Case 1 was carried out by decreasing LPS consumption by 0.18 tonne/hour from base case. The saving cost is about 669,494 Baht/year
- Case 2 was performed by decreasing electrical power consumption by 0.05 MW on top of case 1. The benefit is increase to 770,243 Baht/year.
- Case 3 is a case that like case 2 but further decreasing of electrical power consumption by 0.55 MW. Surprisingly, the saving cost is jumped to about 6,236,357 Baht/year.

- Case 4 is a case on top of case 3 by further decreasing LPSS consumption 0.25 tonne/hour. However, the benefit is not increase as expected. The saving cost for this case is down to 458,067 Baht/year.
- Case 5 is a case on top of case 4 by further decreasing MPS consumption 0.1 tonne/hour. The benefit of this case went down to 291,609 Baht/year.

Based on this study, the best option for cost saving is case 3 with decreasing LPS consumption by 0.18 tonne/hour and decreasing of electrical power consumption by 0.55 MW from base case.

Furthermore, the utility model created by Petro-SIM production program can be used with PI System™, a data management program using in a Petroleum Refining plant, and Microsoft Excel. The results from this study will be an example for other unit to follow.

5.2 SUGGESTIONS

The results of five case studies from manual adjusting may be local value which is not the global value or the best value.

- Set or Adjust function of Petro-SIM is used to find the best value instead of manual adjusting.
- Directly connection between Petro-SIM Production Software and PI System™

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