Steam system optimization (SSO) Assessment

Name of the pilot:

Morvarid Petrochemical Company (MPC)

Measurements Plan

Revision: 06

Project Name: Reducing Greenhouse Gas Emissions through Improved Energy Efficiency in the Industrial Sector in Iran

Submitted to:

United National Industrial Development Organization

Project Management Unit (PMU)

Submitted by:

SSO Iran assessment team

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1- Introduction of the plant

Steam system is one of the most important energy users in process plants. It can be divided into 4 sections: 1) Generation side, 2) Distribution and pipeline, 3) Steam consumers and 4) Condensate recovery and steam traps. Morvarid petrochemical company is located in the Assaluyeh as a part of large special petrochemical zone. The plant's feed is supplied from the production of ethane from South Pars plants for a capacity of 650 t/y. The plant's production capacity is 500,000 t/y of Ethylene Which is Injected into the west ethylene pipe Line, 500,000 t/y of MEG, 50,000 t/y of DEG, and 3,400 t/y of TEG.

This petrochemical plant uses steam as a general heat source, process feed and steam turbine drivers. The main aim of this project is to assess the current situation of system in the company based on steam system optimization tools (SSAT) and on top of that to identify feasible energy conservation opportunities.

This report has written to identify the scope of the project, the required data and measurement plan as a feed of steam system optimization tool (SSAT) and finally finding the energy conservation opportunities. Thus, the first step for finding energy conservation opportunities is studying the current condition of steam system and its components.

2- Scope of work

The complete schematic of a system that will be in the scope of work, is shown in figure 1. In addition, 3 steam boilers exist for supplying the high-pressure steam demand. The related connection could be seen in the right hand of the figure as " HPS TO/FROM OSBT".
Due to SSAT limitations, the simplified schematic has drawn in figure 2. This simpler scheme of the system was selected and used. Since we must use just 3 pressure headers, 2 lines of VHP and HP were combined together. The result of simulations based on gathered data showed that this is the best decision.
A team of experts who have been involved in this project are as below:

- UNIDO international consultant: Mr. Venkatesan Veerasamy
- UNIDO international consultant: Mr. Alexander Antomoshkin
- UNIDO technical expert of PMU: Mr. Mahdi Shakouri
- UNIDO national consultant: Mr. Naser Rezakhani
- AORC energy expert: Mr. Mohammad Monsef

This report has been prepared by Mr. Naser Rezakhani with the help of PMU and reviewed by international consultant.

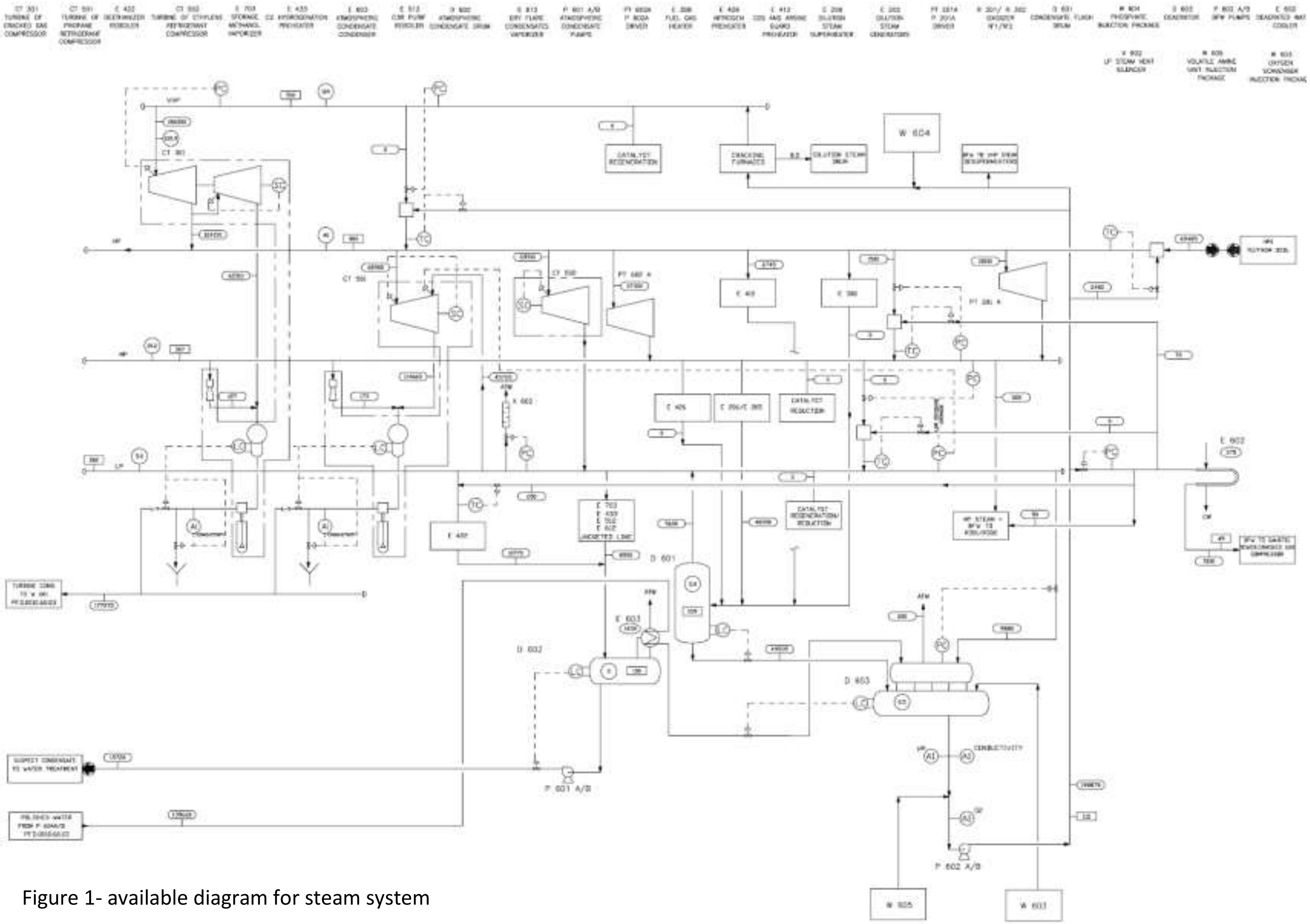


Figure 1- available diagram for steam system

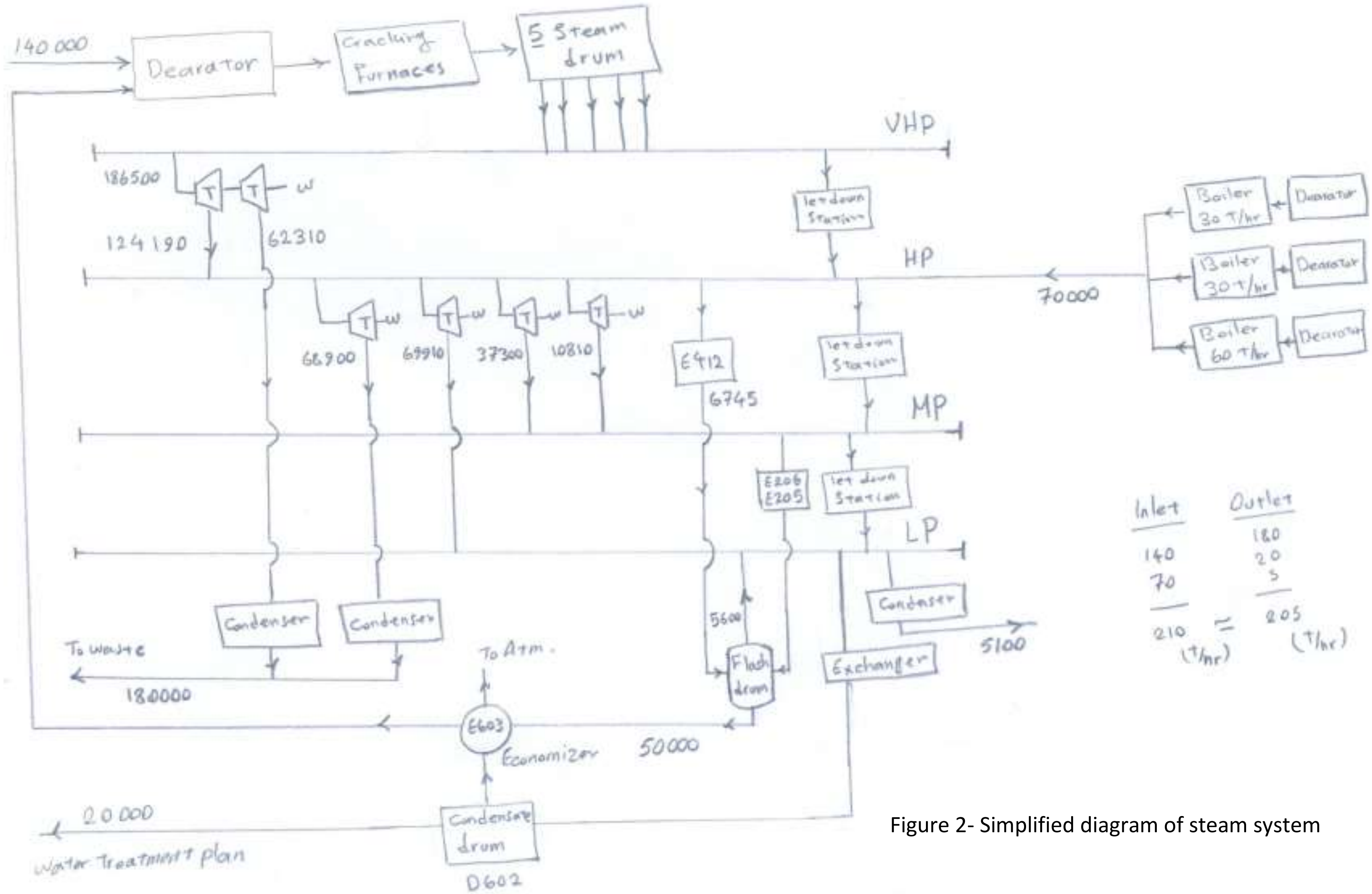


Figure 2- Simplified diagram of steam system

3- Description of the steam system in the MPC

3-1 Generation

Main steam stream is supplying from Assaluyeh utility center (Mobin utility company). In addition to that, there are 3 steam boilers (2×30 t/hr + 60 t/hr) to produce high-pressure steam (HPS) in the plant. During this project measurement, just one of them was at service. Very high-pressure steam (VHP) is producing in cracking furnaces from waste gas. Each steam boiler has individual deaerator and one deaerator is used for VHP production in cracking furnaces. After each cracking furnace, one steam drum is considered.

3-1-1 High-pressure steam generation

Boilers are made in Canada in 2006 by Optima Corporation. Boiler feed water (BFW) is preheated by economizers that are located in the stack of boilers. Inlet and outlet temperatures are available around these economizers and they can heat up BFW about 35^{o}c. BFW flow rate is controlled by water control valves installed in each boiler. So, from the percent of control valve opening, the flow rate of BFW can be calculated. The flow rate of BFW is controlled semi-automatically versus fuel gas consumption. Likewise, the fuel gas flow rate can be calculated from the control valve opening percentage on the fuel gas line.

Total dissolved solids (TDS) in 3 points - including BFW, blowdown and high-pressure steam line are measured regularly in every 8 hours for all boilers, separately. This data are being used for controlling blow down manually. The operational pressure of deaerator can be read from PLC.

The pressure of produced steam is measured with local pressure and temperature transmitter. Each steam boiler has online gas analyzer installed on the stack. It can measure CO, CO_2, NO, NO_2 and O_2. But this device is disconnected now and the analyzer provided by UNIDO.

3-1-2 Very high-pressure steam generation

Process requirement is the main reason for installing cracking furnaces. The waste flue gas use to produce very high-pressure steam (VHP) in a series of heat exchangers. Total capacity is about 205 t/hr. A deaerator provides BFW for 5 cracking furnaces connected to 5 steam drums (5×36 t/hr). The operational pressure of deaerator can be read from PLC and the amount of ventilation can be controlled due to fixing deaerator temperature about 100 ^{o}c.

BFW line has an inline flow meter as well as a temperature indicator. Likewise, the steam line has an inline flow meter as well as temperature and pressure indicators. TDS is examined for BFW and steam drums (blowdown) every 8 hours.

3-2 Distribution

As shown in figures 1 and 2, there are 4 main pressure headers and 3 let down stations. Each let down station - including VHP to HP, HP to MP and MP to LP - has inlet and outlet temperature transmitter. Observation showed that the quality of insulation in all related plants is in a good configuration and the amount of leakage is low and reasonable.

3-3 Consumption

Main consumption of steam in plant related to the compressors and pumps drives. There are 5 turbines in types of back pressure, total condensing, and extraction steam turbine. All turbines have inlet and outlet pressure and temperature transmitters but there is no installed steam flow meter. Turbine is operating between the minimum and maximum limits. There is an rpm range for operational control that used to calculate the minimum and maximum range of required power in each turbine.

Fortunately, the mean isentropic efficiency of turbines have been calculated by MPC staff and are available.

Remained steam is being used in exchangers' networks to provide process energy requirement.

3-4 Condensate recovery

Some condensate recovers from the flash drum and remained sends to wastewater treatment plant. One flow meter is available on condensate line and Total condensate recovery percentage can be calculated by MPC staff. The temperature of recovered condensate is available, but there isn't any temperature gauge around heat recovery exchanger (E603) and it measured by the thermo-gun device. Also, condensers operational data are available in local gauges.

There is reliable data about number and condition of steam traps on the scope of work that can be used in SSAT.

4- Data acquisition and the measurement plan

Tables 1 to 4 show the parameters that should be measured in the next step of the project.

Table 1 - Specified measured data for the generation side

Row	Parameter	Unit	Stream/ Equipment	Location	Device	Value
1	Pressure	barg	Deaerator	Deaerator of Boiler 1 (30 t/hr)	PLC	0.5
2	Pressure	barg	Deaerator	Deaerator of Boiler 2 (30 t/hr)	PLC	0.5
3	Pressure	barg	Deaerator	Deaerator of Boiler 3 (60 t/hr)	PLC	0.5
4	Flow	t/hr	BFW	Boiler 3 (60 t/hr)	PLC	34
5	Flow	m^3/day	Fuel Gas	Boiler 3 (60 t/hr)	PLC	3100
6	Temperature	°C	BFW	Boiler 3 (60 t/hr)	TI – On Site	149
7	Temperature	°C	Steam	Boiler 3 (60 t/hr)	Thermo-gun On Site	350
8	Pressure	barg	Steam	Boiler 3 (60 t/hr)	PLC	45
9	TDS	ppm	BFW	Same for all Boilers	From Lab.	2.5
10	TDS	ppm	Steam Drum (Blowdown)	Boiler 3 (60 t/hr)	From Lab.	34.1
11	Pressure	barg	Deaerator	Deaerator of Cracking furnaces	DCS	0.61
12	Temperature	°C	BFW	After Deaerator of Cracking furnaces	DCS	110
13	Flow	t/hr	Steam (VHP)	Outlet of Steam Drum 1	DCS	17
14	Flow	t/hr	Steam (VHP)	Outlet of Steam Drum 2	DCS	45.5
15	Flow	t/hr	Steam (VHP)	Outlet of Steam Drum 3	DCS	45.3
16	Flow	t/hr	Steam (VHP)	Outlet of Steam Drum 4	DCS	43.3
17	Flow	t/hr	Steam (VHP)	Outlet of Steam Drum 5	DCS	43.8
18	Pressure	barg	Steam (VHP)	Outlet of Steam superheater	DCS	104
19	Pressure	barg	Steam (VHP)	Outlet of Steam superheater	DCS	104
20	Pressure	barg	Steam (VHP)	Outlet of Steam superheater	DCS	104
21	Pressure	barg	Steam (VHP)	Outlet of Steam superheater	DCS	104
22	Pressure	barg	Steam (VHP)	Outlet of Steam superheater	DCS	104
23	Temperature	°C	Steam (VHP)	Outlet of Steam superheater	DCS	500

Row	Parameter	Unit	Stream/ Equipment	Location	Device	Value
24	Temperature	°C	Steam (VHP)	Outlet of Steam superheater	DCS	500
25	Temperature	°C	Steam (VHP)	Outlet of Steam superheater	DCS	500
26	Temperature	°C	Steam (VHP)	Outlet of Steam superheater	DCS	500
27	Temperature	°C	Steam (VHP)	Outlet of Steam superheater	DCS	500
28	TDS	ppm	BFW	Same for all steam drum	From Lab.	3.1
29	TDS	ppm	Steam Drum (Blowdown)	The outlet of Steam Drum 1	From Lab.	7
30	TDS	ppm	Steam Drum (Blowdown)	The outlet of Steam Drum 2	From Lab.	9.1
31	TDS	ppm	Steam Drum (Blowdown)	The outlet of Steam Drum 3	From Lab.	7.9
32	TDS	ppm	Steam Drum (Blowdown)	The outlet of Steam Drum 4	From Lab.	9.9
33	TDS	ppm	Steam Drum (Blowdown)	The outlet of Steam Drum 5	From Lab.	11.5
34	TDS	ppm	Water	Makeup	From Lab.	2
35	TDS	ppm	Water	Turbine Condensate	From Lab.	43
36	TDS	ppm	Water	Liquid condensate	From Lab.	3.3

Table 2 - Specified measured data for the distribution side

Row	Parameter	Unit	Stream/ Equipment	Location	Device	Value
1	Pressure	barg	Steam	VHP Header	DCS	104
2	Temperature	°C	Steam	VHP Header	DCS	500
3	Pressure	barg	Steam	VHP Header	DCS	40
4	Temperature	°C	Steam	VHP Header	DCS	390
5	Pressure	barg	Steam	VHP Header	DCS	16
6	Temperature	°C	Steam	VHP Header	DCS	300
7	Pressure	barg	Steam	VHP Header	DCS	5
8	Temperature	°C	Steam	VHP Header	DCS	190
9	Temperature	°C	Steam	After VHP to HP let down	Thermo-gun On Site	400
10	Temperature	°C	Steam	After HP to MP let down	Thermo-gun On Site	300
11	Temperature	°C	Steam	After MP to LP let down	Thermo-gun On Site	190

Table 3 - Specified measured data for the consumption side

Row	Parameter	Unit	Stream/ Equipment	Location	Device	value
1	Min Shaft power	kW	CT 301/Turbine	Inlet of CT 301	DCS	17597
2	Max Shaft power	kW	CT 301/Turbine	Inlet of CT 301	DCS	23413
3	Pressure	bar	Steam	CT 301/Condenser	PG – On site	-0.8
4	Min Shaft power	kW	CT 501/Turbine	Inlet of CT 501	DCS	18353
5	Max Shaft power	kW	CT 501/Turbine	Inlet of CT 501	DCS	19361
6	Pressure	bar	Steam	CT 301/Condenser	PG – On site	-0.8
7	Min Shaft power	kW	CT 502/Turbine	Inlet of CT 501	DCS	8498
8	Max Shaft power	kW	CT 502/Turbine	Inlet of CT 501	DCS	5705
9	Steam Flow	t/hr	PT 602 /Turbine	Inlet of CT 602	DCS	35.7
10	Steam Flow	t/hr	PT 201 /Turbine	Inlet of CT 201	DCS	7.8
11	Flow	t/hr	Steam -HP	Uses by E412	DCS	6.8
12	Flow	t/hr	Steam-HP	Uses by E308	DCS	4.4
13	Flow	t/hr	Steam-MP	Uses by E206/E205	DCS	48.6
14	Flow	t/hr	Steam-LP	Uses by E422	DCS	10.8
15	Flow	t/hr	Steam-LP	Uses by E422	DCS	9.7
16	Flow	t/hr	Steam-LP	Uses by E703/E433/ E512/E612	DCS	7.5

Table 4 - Specified measured data for the condensate recovery side

Row	Parameter	Unit	Stream/ Equipment	Location	Device	Value
1	Temperature	°C	Condensate	Condensate header	DCS	102
2	Temperature	°C	Condensate	Turbine Condensate	DCS	66.25
3	Temperature	°C	Condensate	Inlet of E 603	Thermo-gun On Site	43.2
4	Temperature	°C	Condensate	The outlet of E 603	Thermo-gun On Site	65.2

5- Process simulation based on steam system assessment tool

5-1 The Assumption

Due to the fact that SSAT model has some limitations for simulation as well as availability of data for the project goals, we need to consider below assumptions for our developed model:

1. As shown in figure 1 there are 4 pressure headers in the plant. Since the SSAT can accept just 3. The simulation was done in different configurations. The result show that the best

and more reasonable state is a combination of VHP and HP. So, the final configuration including HP (VHP+HP), MP and LP.

2. Steam supply from 3 different sources; internal steam boiler, hydrocracker superheater and Mobin utility factory. Efficiency measurements that were done by Morvarid staffs determine the internal boiler efficiency. This value is about 87%. There isn't any data about Mobin utility factory. In addition, the calculation of steam production efficiency in hydrocrackers is unreasonable. Thus, the default value of SSAT was selected for the efficiency factor.

5-2 The Simulation

The SSAT tool is used to simulate the process in the scope of work. The simulation was done considering the gathered data which represented in table 1 to 4 and shown in the environment of SSAT tool in table 5.

Some parts of entry data directly used from measurements and the remained parts have been calculated. The amount of steam that uses by a group of steam turbine pumps is calculated by adding all steam consumption in each group of turbines. In addition, the steam leak is calculated by the number of steam traps in each pressure level and the approximate timing of plant last trap testing and maintenance program.

Table 5 - Morvarid Petrochemical Company case description

Data	Input Data		Notes/Warnings
Site Power Import (+ for import, - for export)	200	kW	Power import + site generated power = site electrical demand
Site Power Cost	0.0604	$/kWh	Typical 2003 value: $0.05/kWh
Operating hours per year	7000	hrs	
Site Make-Up Water Cost	3.2000	$/m3	Typical 2003 value: $0.66/m3
Make-Up Water Temperature	43	°C	
Boiler fuel - Choose from this drop-down list			Natural Gas
Site Fuel Cost	0.05	$/Nm3	Typical 2003 value: $0.22/Nm3
Note: Fuel HHV is 40,144 kJ/Nm3 (54,220 kJ/kg)			
For user defined fuels, enter HHV	46500	kJ/kg	
Steam Distribution			
High Pressure (HP)	104	barg	
Medium Pressure (MP)	16	barg	
Low Pressure (LP)	5	barg	
HP Steam Use by Processes	11.4	t/h	
MP Steam Use by Processes	55.5	t/h	
LP Steam Use by Processes	43.8	t/h	
Steam Turbines			
Do you have a steam turbine installed between HP and LP?			Yes
Do you have a steam turbine installed between HP and MP?			Yes
Do you have a steam turbine installed between MP and LP?			No
Do you have an HP to condensing turbine installed?			Yes
For a Condensing Turbine, please define how the turbine operates and then provide the supplementary information below:			
Mode of operation			Option 1 - Define fixed power generation
Option 1 - Fixed power generation	41766	kW	

Data	Input Data		Notes/Warnings
Steam Traps			
Number of traps at each pressure level			
Traps on HP header	0	traps	
Traps on MP header	20	traps	
Traps on LP header	130	traps	
Select the approximate timing of your last trap testing and maintenance program			< 1 year ago
Boiler			
Method for specifying boiler efficiency			Option 2 - Enter user-defined value
Option 2 - Enter efficiency (%)	85	%	
Blowdown Rate (% of feedwater flow)	2	%	
Do you have blowdown flash steam recovery to the LP system?			No
Please select how you wish to define your HP generation condition and then provide the supplementary information below if required:			
Method for specifying HP generation condition			Option 2 - User-defined superheated conditions
Option 2 - Enter temperature	500	°C	
Configure the operation of your HP to LP turbine(s) using the options below:			
HP to LP Steam Turbine(s)			
Isentropic efficiency	73.5	%	
Select the appropriate turbine operating mode			Option 3 - Operation within min/max limits
Option 3 - How do you wish to define the operating range?			Specify range for power generation
Option 3 - Minimum power generation	5707	kW	
Option 3 - Maximum power generation	8497	kW	

Data	Input Data		Notes/Warnings
Configure the operation of your HP to MP turbine(s) using the options below:			
HP to MP Steam Turbine(s)			
Isentropic efficiency	75	%	
Select the appropriate turbine operating mode			Option 2 - Fixed operation
Option 2 - How should the fixed turbine operation be defined?			Specify fixed steam flow
Option 2 - Fixed steam flow	43.5	t/h	
Configure the operation of your HP to Condensing turbine(s) using the options below:			
HP to Condensing Steam Turbine(s)			
Isentropic efficiency	73	%	
Select the units of measure to specify the condenser pressure			bara
Condenser pressure (bara)	0.5		
Letdowns / PRVs			
HP to MP - Is desuperheating water used?			Yes
If yes, enter control temperature	300	°C	
MP to LP - Is desuperheating water used?			Yes
If yes, enter control temperature	190	°C	
Deaerator			
Vent (as % of boiler feedwater flow)	1	%	
Select the appropriate deaerator operating mode			Option 2 - User-defined pressure
Option 2 - Specify pressure	0.61	barg	
Feedwater Heat Recovery System			
Heat recovery exchanger on the condensate tank vent?			Yes
If yes, enter approach temperature	22	°C	
Heat recovery exchanger on boiler blowdown?			No
Process Condensate			
Condensate return temperature to tank	102	°C	
HP condensate recovery	73.68421	%	
MP condensate recovery	100	%	

Data	Input Data		Notes/Warnings
LP condensate recovery	60.24096	%	
Do you flash condensate to MP steam?			No
Do you flash condensate to LP steam?			Yes
Steam Trap Losses and Steam Leaks			
Choose a method for estimating steam losses			Option 1 - Losses automatically estimated by model (Model defaul
Note: Calculated values for current loss and leak rates based on current user inputs are:-			
HP header - Trap failures: 0, Loss per trap 0.130 t/h - Total trap loss = 0.00 t/h. Steam leaks: 0, Loss per leak 0.032 t/h - Total leaks = 0.00 t/h.			
MP header - Trap failures: 1, Loss per trap 0.024 t/h - Total trap loss = 0.02 t/h. Steam leaks: 0, Loss per leak 0.006 t/h - Total leaks = 0.00 t/h.			
LP header - Trap failures: 4, Loss per trap 0.009 t/h - Total trap loss = 0.03 t/h. Steam leaks: 1, Loss per leak 0.002 t/h - Total leaks = 0.00 t/h.			
Insulation Heat Losses			
Choose a method for specifying heat losses			Option 2 - Percentage heat loss on each header (Model default)
Option 2 - % of heat loss on HP header	0.1	%	
Option 2 - % of heat loss on MP header	0.1	%	
Option 2 - % of heat loss on LP header	0.1	%	
Note: Losses calculated as the percentage of heat flow entering each header			
Note: Current values for heat entering headers are: HP 277695 kW, MP 46354 kW, LP 54099 kW - These may change when the model is updated			

6- Steam system energy conservation opportunities (ECOs)

As far as the SSO team of MPC have done site visits for identification of energy conservation opportunities (ECOs) as well as the simulation of MPC steam system in SSAT, potentials for improvement have been identified. In the below description, the above mentioned ECOs have been categorized in three categories including distribution, users and condensate return.

Boilers

No particular issues with boilers had been observed during the site visit. Additional sources of HP steam are 5 furnaces of Olefin unit, each has a steam drum. All steam drums have no insulation, losing heat to the atmosphere.

Steam distribution system

The distribution system has a modern design, properly sized and drained. TD traps are used for headers drainage.

Steam users and steam trapping

One of the users is the VHP turbine, driving a compressor for compressing a crack gas from 0.5 bar to 30 bar. Turbine is a condensing extraction type, providing HP steam to technology. It was found out that the condenser pressure currently is 0.5 bara, while should be (according to documentation) 0.2 bara. As a result, the cooling seawater consumption is now 150,000 m^3/h instead of specified 50,000 m^3/h. It appeared that the condenser had no service and cleaning for the last 3 years, therefore the heat transfer coefficient dropped due to scaling.
All tracers are properly designed and drained by inverted bucket quick fit traps.
Several heat exchangers (vapor heaters) have a problem with condensate removal. Investigation and steam loads calculations showed that most likely the stall point occurs, mostly at summer time. Heaters are using LP steam at 2.8 bar pressure. The steam load in summer time reduces. There is no automatic control of steam supply, so personnel reduces pressure using a manual valve. Condensate line after the exchanger is rising 8 meters up, to the local condensate tank. The pressure drop across the condensate valve is close to 0 bar, therefore condensate is not removed from the heat exchanger and vapor temperature drops. Personnel has to open the drain and to blow steam to drain. As a result, about 200 kg/h of condensate is lost. Condensate line sizing and design should be reconsidered.

Condensate return

Condensate return rate from Olefin unit is about 60% as compared to 90% initially designed.
Apart from the mentioned heat exchangers problem and 3 or 4 visible steam leaks, no reasons for the low condensate return rate were identified. The additional careful investigation, including traps survey, should be made.

Identified opportunities for improvement

All opportunities had been discussed with the SSO team, priorities are seen as follows:

- Careful steam traps survey required. The problem is that it takes 6 months to order traps for replacement.
- Turbine condenser should be cleaned, to improve vacuum in it to the designed level of 0.2 bara.
- Steam loads and stall point for vapor heat exchangers should be checked.

SSAT model steam conservation projects and results

That projects that selected and defined on SSAT model are listed below:

1. Install blowdown flash to LP
2. Modify operation of HP to condensing turbine
3. Install blowdown heat exchanger
4. Increase HP condensate recovery
5. Increase LP condensate recovery

The result of steam system assessment tool shows these selected projects are capable to lead a considerable energy conservation in the Olefin Unit (based on natural gas consumption) with the amount of 5.8% and total cost reduction will be around 8.5%. The more detail data can be found on table 6.

Table 6. The result of implementing conservation opportunity

Cost Summary	Reduction	
Fuel Cost		5.8%
Make-Up Water Cost		40.3%
Total Cost		8.5%
CO2 Emissions	21568 t/yr	5.8%
NOx Emissions	43 t/yr	5.8%
Boiler Duty	17134 kW	5.8%
Fuel Consumption	1536 Nm^3/h	5.8%
Boiler Steam Flow	18 t/h	5.8%
Make-Up Water Flow	12 m^3/h	40.3%

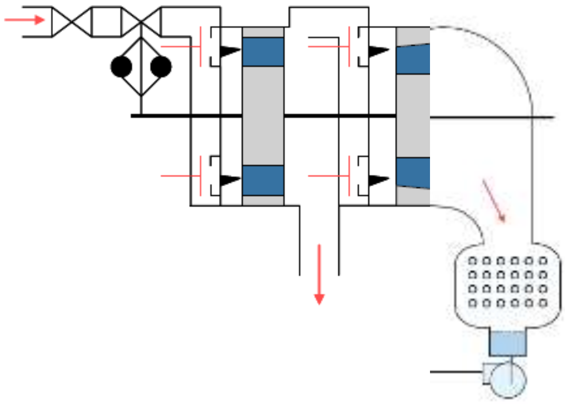
7- Conclusions and recommendations

After defining a measurement plan by national expert of the project, measurements were done by participation of PMU, national expert and internal team of MPC. Thereafter, a model for simulation of the MPC steam system developed by national expert. Then, PMU and international expert had a site visit in order to identify energy conservation opportunities. Lastly, SSAT model revised in order to consider priorities identified energy conservation opportunities. The result of steam system assessment tool (SSAT) shows selected projects are capable to lead a considerable energy conservation in the Alkylation site (based on natural gas consumption) with the amount of 5.8% and total cost reduction will be around 8.5%.

As the energy management system (EnMS) is in place within the company, it is recommended to put all the identified energy conservation opportunities of this program within the ECO list of EnMS. Thereafter, it is suggested that the energy team of the company work on prioritizing each ECO and develop an action plan for implementation. It's obvious that for getting the better result, the energy team shall present outputs of this program to the top manager of the plant, in order to get his/her commitment to support required investments if applicable.

Annex 1: Calculation of Isentropic efficency for turbines (Special case in the pilot for improvement)

Calculation of Isentropic efficency for extraction-condensing turbine – 2 stages **– CT301**

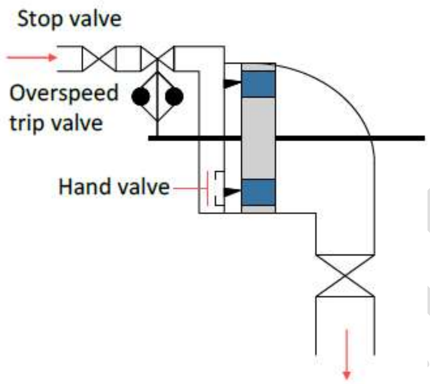


T1=500 C
P1=107 barg
H1=-12610 kg/kJ

T2=386
P2=43 barg
H2=-12790 kg/kJ
H2s=-12880 kg/kJ

Eff=67%

Backpressure turbine – single stage **– CT502**

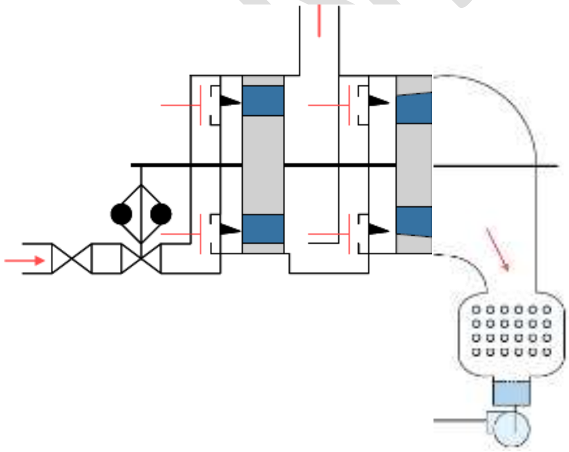


T1=400
T2=185
P1=42

P2=5.5
H1=-12760
H2=-13120
H2s=-13180

Eff=85.7%

Admission-condensing turbine – 2 stages **– CT501**



T1=40
T2=285
P1=42

P2=5.5
H1=-12760
H2=-12940
H2s=-13180

Eff=42.8%