EBSILON – USAGE & EXPERIENCE

GUJARAT INDUSTRIES POWER COMPANY LTD.

SURAT LIGNITE POWER PLANT

Surat Lignite Power Plant (4 x 125 MW)

Unit	Capacity	Boiler & Turbine make/ Year of Commissioning
Unit-1 &2	2 x125 MW	LLB, BHEL/ SIEMENS / Yr 2000
Unit-3&4	2 x125 MW	BHEL / SIEMENS / Yr 2010

GIPCL - Company Profile

An IMS (9001, 14001, 18001, 50001) Company, Established in 1985

TOTAL: 1009.4 MW

At Baroda

Gas Based Power Plant
145 MW (Year 1992) 165 MW (Year 1997)

At Surat

4x125 MW Lignite Based CFBC Units
Phase-I (Year 2000),
Phase II (Year 2010)

At Surat

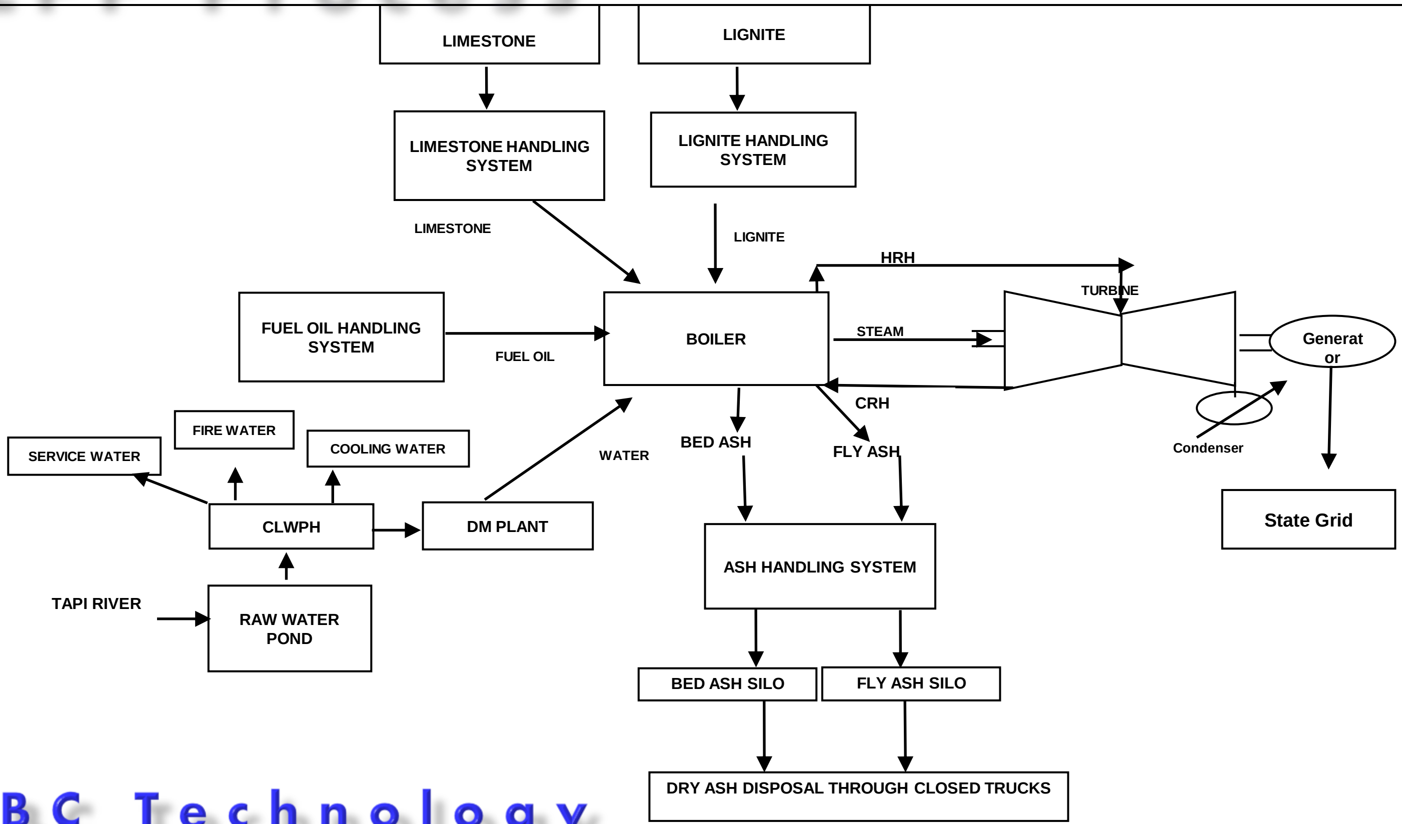
Captive Lignite & Limestone Mines

112.4 MW Wind Power-2016

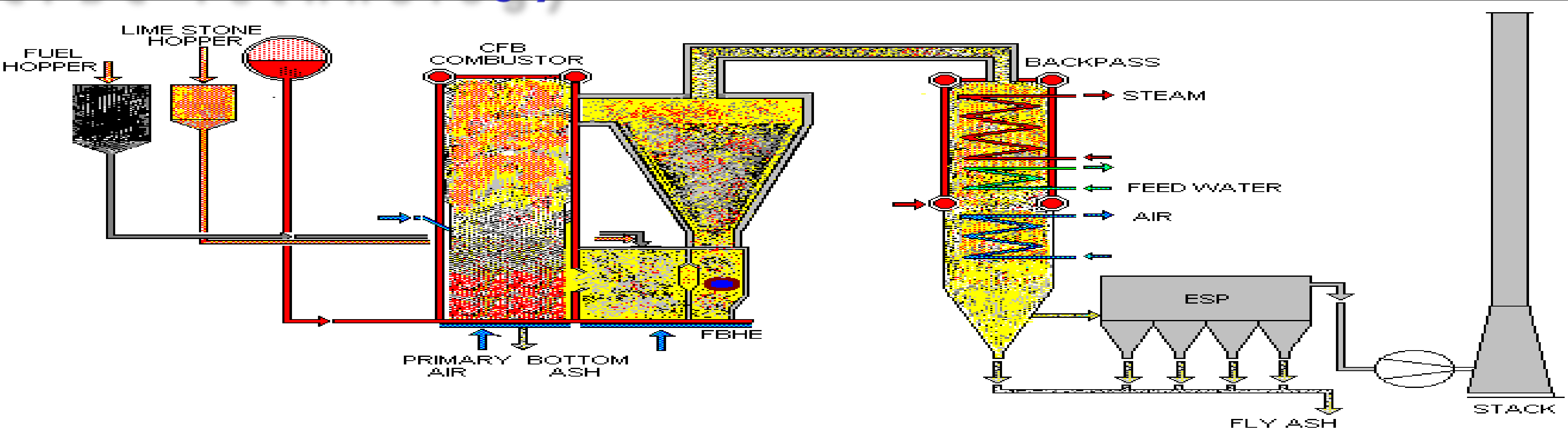
2x1 MW Distributed Solar Power cum Agriculture Pilot Projects -2016

5 MW Solar Plant at SLPP
(Year 2012)
80 MW at Charankha Solar Park, Gujarat

SLPP Process



CFBC Technology



EBSILON License Handover Ceremony

1st May 2012, New Delhi

IGEN PHASE –II Program : Road Map

Output 1 – To develop capabilities for usage of diagnostic tool (Ebsilon Professional) for Identifying Energy Efficiency Measures in Thermal Power Sector

Output 1.1 Supply of Ebsilon licenses (1st May 2012)

Output 1.2 & 1.3 Two weeks training & Exercise on Ebsilon in four batches

(*4th Jun'12 to 15th Jun'12*, *18th Jun'12 to 29th Jun'12*, *29th Oct'12 to 9th Nov'12* and *10th Dec'12 to 21st Dec'12*)

Output 1.4 Further Exercise at Plant Locations

Output 1.5 Evaluation at Plant Location

(17th September to 22nd September 2012)

Output 1.6 Preparation of Case Study On Energy Saving Potential (19th April to 22nd April 2013)

Providing Support & Updates of Ebsilon Software free of Cost till FY 2017-18

EBSILON Professional Software – Introduction

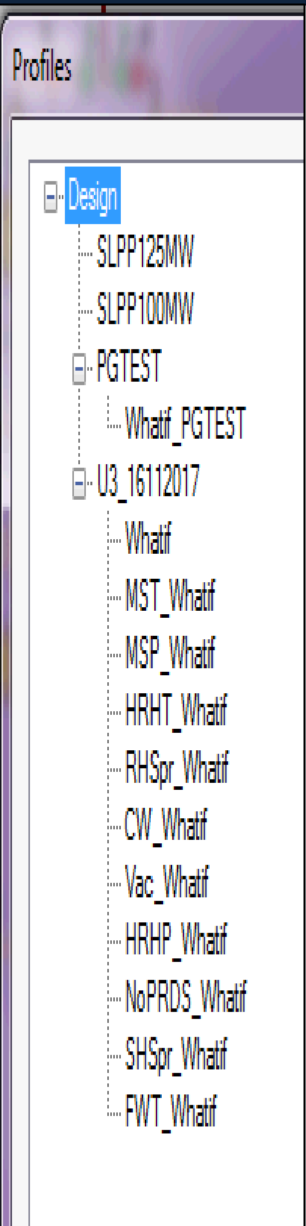
EBSILON[R] Professional Software is a powerful, precise & accurate tool which supports in the planning from the detailed design stage of the plant right up to the feasibility study of any modification or retrofitting ideas in view of design & optimization. The characteristic features are:

- Intuitive and comfortable Modeling of plant due to the Window-based graphical user interface.
- Mapping of topology of the plant in a precise way by means of the Comprehensive Component Library just by drag & drop of components and topology made to alive by the use of Comprehensive Data Library.
- Any thermodynamic cycle can be modeled – Ebsilon provides high flexibility of the system and the universality of the approach.
- For the requirement of conventional power plants like us - there are no limits to the modeling options. Also user-specific processes/ components can be modeled.
- The universal calculation approach and the powerful solution algorithm ensure a fast and reliable calculation of the system parameters.
- An intelligent error analysis and the comprehensive built-in help assist the user during modeling process.
- Design a performance optimized plant by introducing specific parameters into the model.
- Calculate the effect of component degradation, study various load conditions & changes in environment condition & other parameters.
- Simulate the operation of newly developed component in a cycle.

EBSILON Professional Software – How it helped us

- **Identify** Heat Rate deviations/Efficiencies degradation - component wise and system & Subsystem wise
- **Identify** Areas/ Opportunities having Energy Saving Potential.
- **Evaluate** Short & Long term Energy Efficiency measures for achieving projected saving
- **Comparison of** Actual Performance with "Guaranteed Performance" or with any other Reference performance and Simulation of actual performance at different conditions or modes of operation
- **Assessment of** The impact of individual equipment performance's variation on overall plant efficiency and Heat Rate
- **Assessment of** The impact of different retrofit options to determine the energy efficiency measure

How We Make the Use of The EBSILON



Profile Structure

From SLPP total 6 executives had acquired training in the use of software during FY 2012-13. After getting trained in using the software we have done lot of work in getting conversant with the software and made proper working system on prepared models. Details of establishing the system are listed here:

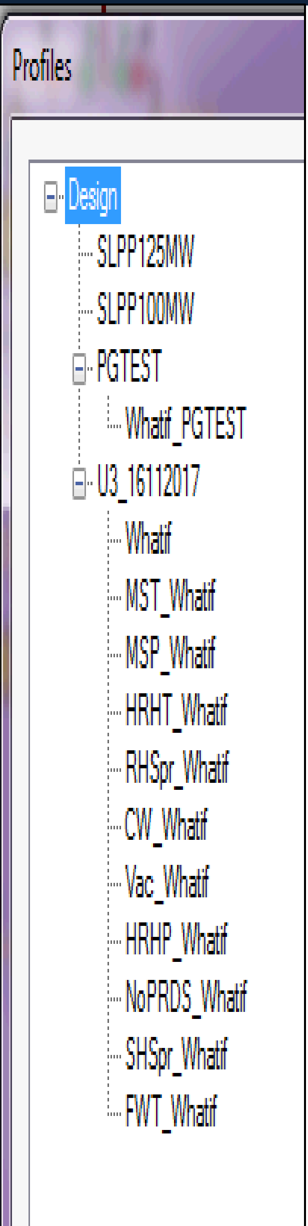
1. Separate Design model of all Units were prepared by components & topology matching with the plant schemes and parameterize the model by using data from the ‘Heat Balance Diagrams’ at different load conditions supplied by the OEM. In this way design characteristics of plant equipment were fixed.

2. Design Models were freeze after checking generated results found to be in line with OEM data.

3. Based on design model, PG Test results/values were checked in a sub profile parameterized by PG test data. This proved the integrity of plant performance with the committed by the OEM.

4. For easy capturing of plant parameters required for assessment of plant performance from the running unit, a screen/ report log was designed in the DCS of each unit to display/generate log of previous 15 minutes average parameter according to the performance test codes.

How We Make the Use of The EBSILON



Profile Structure

5. For quick data transaction with the model, two standard templates were prepared in MS excel. One for data upload in to the model, second for result download from the model.
6. Sub-profile (Child Models) was created from design model to generate As-On-Date profile (Operating model) and 15 Minute average data taken from DCS is uploaded in Operating model to generate As-on-date performance.
7. Further No of Sub profiles of Operating Models were created and they were made to behave like Operating model by transferring nominal values from Operating model to the Child models (***This step may be called as DNA transfer to next generation***). Now these Sub-profiles can be used as What-ifs profiles to compare with the results of Design OR PG Test results & to analyze <u>Heat Rate Deviation due to change in various parameters or Condition</u> like change in MS/HRH temp & pressure, Condenser vacuum, CW inlet temp., RH & SH Spray, FW temp at the inlet of Economizer, 'without PRDS' etc.
8. Developed a template for download/upload of nominal values from the Operating Model (which itself a sub-profile of Design Model) to its Child Models. **This is unique work by us** and it has resulted in fast processing. (***In Ebsilon Nominal values gets copied automatically from Design Profile to its Sub profiles–but not from parent Subprofile to Child Subprofile***)
9. On the basis of this structure in Ebsilon, which we are consistently tracking individual unit performance on monthly basis or as per the requirement.

How We Make the Use of The EBSILON

Development of System Station Level:

- ✓ The consistent use of the software become possible only due to continuous support, follow-up & mentoring by top management.
- ✓ From SLPP there were total 6 executives had imparted training in the use of software in Yr2012-13. Further 15 more executives were trained chosen from various deptts in the use of software.
- ✓ At SLPP, Energy Management Cell is working since Yr2010 in which more than 30 BEE certified Energy Auditors/Energy Mangers are members of the cell who belongs to different deptts & disciplines.
- ✓ The core team of the EM Cell designed a 'Suggestion format' which is kept in the common server and all the employees can access the format. Any employee who wish to put his suggestion for discussion in meeting can drop in suggestion box or can send through e-mail.
- ✓ Energy Management Cell meetings are being conducted once in a three months under the chairmanship of Station Head. All the suggestions received are reviewed and implementable projects are accepted and conveyed to the concerned department for implementation. In the implementation process, the suggestor of idea has to monitor the project & report the outcome.
- ✓ IF any idea needs detailed analysis through the Ebsilon, then it is handed over to the core team members who are well acquainted with the software for further analysis and put up result in the EM Cell Meeting for discussion.

Benefits Achieved

Before we adopted use of Ebsilon, formulated MS excel sheets were being used for Efficiency calculation and HeatRate deviations/Efficiencies degradation of System/Subsystem/equipment in which it was not possible or very tedious to see the effect of change of one parameter over the entire system. After we started using the Ebsilon, we had analyzed & solved many tedious & complex problems like :-

- ✓ Evaluation of idea of CEP discharge pressure reduction by stage reduction (retrofit option) against idea of Using VFD and study of its effect over turbine system stability– ***After analyzing through Ebsilobn we opted stage reduction which resulted in achieving 155kW power saving on permanent basis in two Units. In remaining two units we are going to implement this year***.
- ✓ Comparative study of Increase in Boiler Draft power & load-ability loss (due to disturbance in Null pressure of boiler) of boiler due to APH tube leakage / FG Duct Air ingress – ***We are facing problem of heavy corrosion due to Chlorides in lignite which is badly affecting APC of Units. Frequent corrective action are being taken and Ebsilon helping us in assessment of work output*.**
- ✓ Study of degradation of Turbine heat rate or loss of MW or Increase in MS flow due to high CW inlet temp because of poor performance of cooling towers. ***Based on study results Phase-I Units CT fills were replaced in 2012-14. Now we have decided for same in Phase-II units***.
- ✓ Calculation of energy consumption of Air Compressors due to change in discharge pressure and ambient temperature of compressor room etc.- **3.6 KW power saving was achieved by diverting hot air throw from motor's cooler outlet to compressor suction. 11.4kW saving was achieved by reducing discharge pressure by 0.5kg/cm^2**.

Benefit Achieved…

- ✓ We carrying out Condenser tubes cleaning work every second year. Earlier no one was able to tell how much improvement we get from this work. With the help of EBSILON it become possible to calculate accurately gain in GTHR, in terms of MW, Change in Condenser TTD, LMTD & Effectiveness. It become possible only due to Ebsilon – ***normally 7 to 8 mbar improvement occurs in condenser vacuum which is equivalent to 10 kCal/kWh gain in TGHR or 0.5 to 0.6 MW load rise. This is sufficient to justify the activity cost.***
- ✓ Similarly Accurate calculation of power saving/improvement in heat rate due to maintenance work carried out on cooling towers become possible.
- ✓ Recovery of heat energy available in bed ash drained off from the Combustor and idea of utilization of this heat in turbine system (injection of heat from external source).
- ✓ What would happen if De-Aerator control station which is provided before LPH-1 is shifted after LPH-3. ***By the use of Ebsilon we could tell that it will result in 72kW$_{th}$ more heat recovery thereby GTHR will improve by 0.167 kCal/kWh***.
- ✓ Unit-2 HPH-6 internal inspection was carried out (*As its TTD was running higher & being tracked through Ebsilon*) and damages were found in the parting plate. The problem was repeated again after two year and captured in performance mapping. Again the HPH was opened during overhaul and parting plate leakage attended. ***We were able to save 38 kCal/kWh by attending the short circuiting inside HPH***.

Benefit Achieved…

Apart from Savings in Heat Rate & Power Consumption,

Studied the ACW-PHE-CCW system & prepared PHE characteristics. The result was circulated & discussed in view of awareness about the system. The study of this idea has been done in detail but execution is not possible due to some constraints.

The idea of pre-heating of condensate from the heat of bed material drained from the combustor in ash cooler was studied & sent to OEM for further evaluation & if it is okayed by them, then it will be a huge saving for us.

Ebsilon is helping us in making Pre & Post Performance Comparison Report of Units due to AOH/COH year to year.

Evaluation of Energy saving opportunities or energy conservation ideas is also being done and had proved accurate & beneficial.

Frequent analysis of heat rate, heat rate deviations & boiler efficiency has become easy & accurate. Monthly record of Unitwise performance is being maintained on routine basis.

Summary of Energy Conservation Projects Implemented

Year	Total Nos. of Energy conservation projects implemented	Total Electricity saving(MU)	Total lignite saving in MT
2013-14	8	14.9632	23806
2014-15	27	18.802	24874
2015-16	11	9.286	35929
2016-17	11	12.791	15230
Total	57	55.8422	99839

SLPP solemnly declares that for most of the above implemented projects, Ebsilon Software has been used extensively in identification of energy saving opportunities, if already identified (came through suggestion) then it is used in establishing feasibility, calculation of exact improvement, saving & payback calculation. We are also taking help of the Ebsilon in calculation of improvement before & after any major maintenance activity which is related with energy efficiency or load-ability improvement. The use of Ebsilon has helped in growing our confidence.

Overall Views on EBSILON Use

Positive Points

User friendly, very helpful, accurate and reliable result within some mili seconds. Use of MS Excel based templates has been obsolete. We have been switched over to Performance Reporting of all units / systems on daily/monthly basis calculated from Ebsilon only. It is also helpful in evaluating the EC ideas. Various What-If conditions can be simulated and analyzed. Analysis of process at different operation modes, component degradation is very easy. Very strong Component & Data Library helps in a great way .

Negative Points

Initial development of design profiles & child profiles takes a lot of time. Preparation of input and output data files (templates) is also very careful and tedious job in the initial phase.

Removal / troubleshooting of the error which generally occurred during initial run or during day to day work (Generally occurs due to entry of wrong data value or unit) is not an easy task for an experienced user also.

Day to day working on a ready model is also time consuming. Inputting data, error removal if any, then checking & validation of running model takes a lot of time.

Scrutiny of output data for relevance & correctness (which may arise due to wrong data input or wrong use of measurement unit) takes a lot of time.

Same model has to be made operative to study a different aspects (What-ifs) by proper tuning (includes switching off/on some components, measurement, Change in logics, logics etc) separately for each aspect. To understand this suppose if someone want to see the effect of change of vacuum in MW or in MS flow, in both condition model has to be tuned separately.

Some Suggestions

- ✓ Effective utilization of this software requires establishing a separate cell of experienced, interested & dedicated staff with free from other assignments as working with it demands deep concentration & lot of time. It needs tuning or customization of model differently, sometimes change in topology of the model for different tasks or ideas. So proper selection of manpower is utmost necessary.
- ✓ If a Power Generation company has developed a strong team of Ebsilon users, then this software can effectively be used in preparation of design stage bid documents as well as evaluation of bids submitted by OEMs when ordering for new Unit/ System.
- ✓ Condenser performance can be compared with earlier condition at same heat load & CW inlet temp after any major activity like tube cleaning or plugging a leaking hole or flow reduction (suppose due to leakage in CW line).
- ✓ Equivalent fan (ID, FD PA) model may be prepared for comparative study of boiler draft power at same isentropic fan efficiency.
- ✓ Model of Individual equipments like compressor, Cooling towers etc can be made for periodic performance monitoring. There is no need to study on model of complete plant.
- ✓ With the help of Ebsilon, at any operating load, one can confidently point out faulty parameter and say how much it should be, how much it has been deviated from the design. However sometimes it takes time for proper tuning.

Expectations from BEE/CEA

We were imparted very basic training on Ebsilon during 2012-13 which was just to make us acquainted with the use of software and was mainly focused at TG cycle & Pilot modeling of Boiler. As of now I would like to say that we are not so much fluent with the boiler side components/model like that with turbine side model/components with which we have become well acquainted.

Yet, at SLPP, we have developed & run fully fledged model of CFBC boiler covering all the major components / equipment by using available components. But it generates lot of errors when it is parameterized with other set of data. It is found that some components are more useful & easy in preparing /representing the topology of the CFBC technology boilers but those components are not supported by the life time license of 'Ebsilon Professional' supplied to us. In this context CEA is requested to -

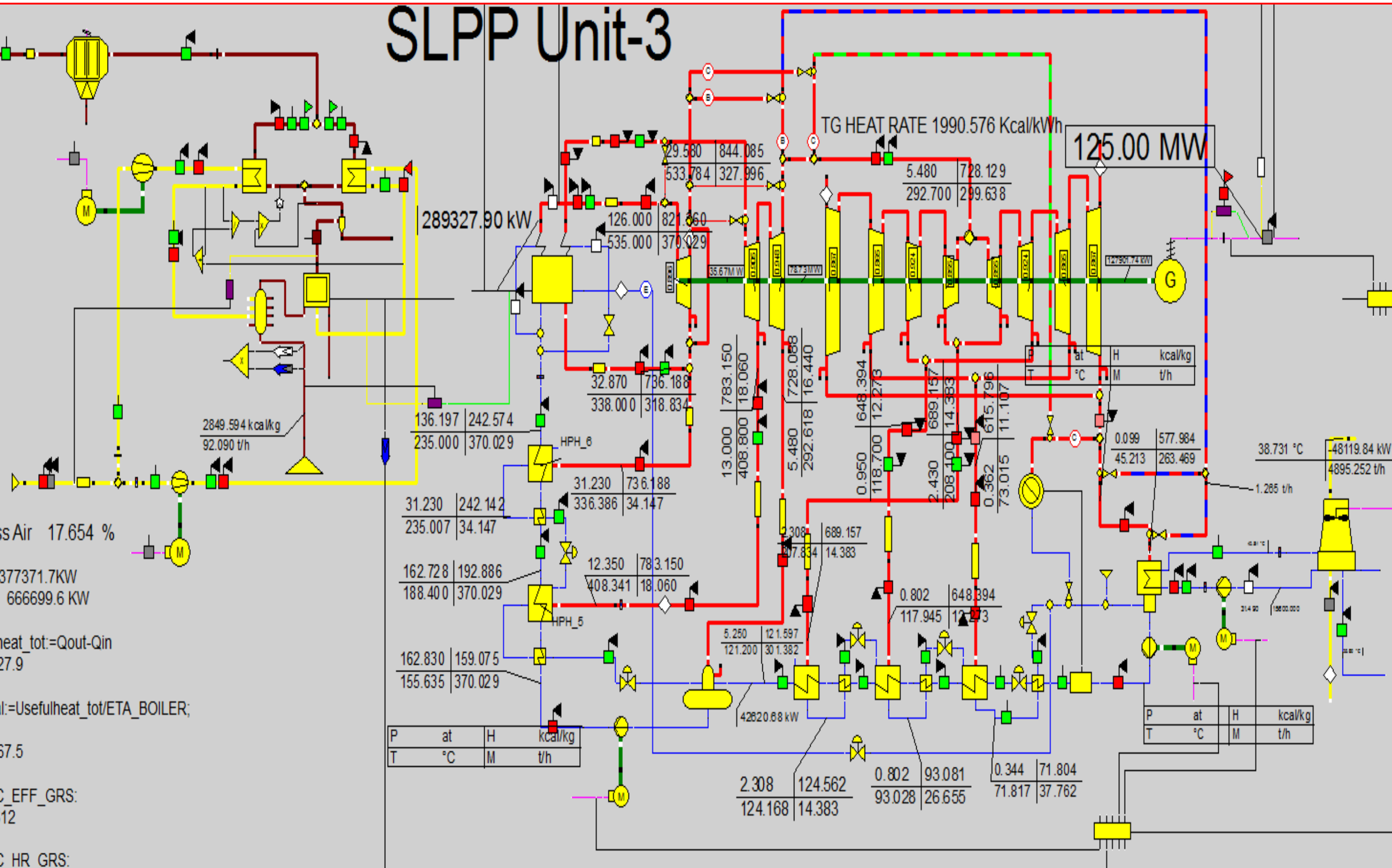
- ❖ Arrange an advanced and exhaustive training on the use of components designed for modeling of Boiler and extension of license on use of boiler components suitable for CFBC boilers and transient behavior of components, scripting or programming in Ebsilon which is a great facility available with the software.

- ❖ Arrange to unlock the feature of saving a project in HTML format so that model analysis can be discussed/ presented in meetings / at remote locations without using the HASP key.

THANK YOU FOR YOUR ATTENTION

Some Examples of Work Done with the help of ‘EBSILON’

Design Model



Heat Distribution	
Heat Rejected in Condenser	163.53 MW
Heat Used in HPH-6	21.38 MW
Heat Used in HPH-5	14.55 MW
Heat Used in LPH-3	9.86 MW
Heat Used in LPH-2	8.60 MW
Heat Used in LPH-1	7.12 MW
Heat Used in Drain Cooler + GSC	0.99 MW
Heat Used in Dearator	25.84 MW
Heat Remained in Condensate	15.85 MW
	267.72 MW

Plant Economy	
Gross power	125.0 MW
Net power	121.2 MW
Gross Efficiency	33.96 %
Net Efficiency	32.93%
UnitHeatRate(Gross)	2532.3 kcal/kWh
UnitHeatRate(Net)	2611.9 kcal/kWh
TGHeatRate(Gross)	2022.1 kcal/kWh
TGHeatRate(Net)	2085.6 kcal/kWh
Boiler Efficiency	78.61 %
Coal consumpt.	92.09 t/h

Exess Air 17.654 %

Qin:= 377371.7KW
Qout:= 666699.6 KW

Usefulheat_tot:=Qout-Qin
289327.9

Q_Coal:=Usefulheat_tot/ETA_BOILER;

368067.5

UNIT_C_EFF_GRS:
0.339612

UNIT_C_HR_GRS:
2532.3

UNIT_C_EFF_NET
0.329271

UNIT_C_HR_NET:
2611.9

AIR HEATER	
Seal Leakage	0.107450 %
Corrected Gas Out Temp	148.329685 °C
Efficiency	56.71 %
XRATIO	32.83 %

DATA for SAN-KEY Diagram	
TURBINE INPUT	344.7 MW
GENERATOR OUTPUT	125.73 MW
CONDENSER LOSSES	177.10 MW
OTHER LOSSES	41.89 MW

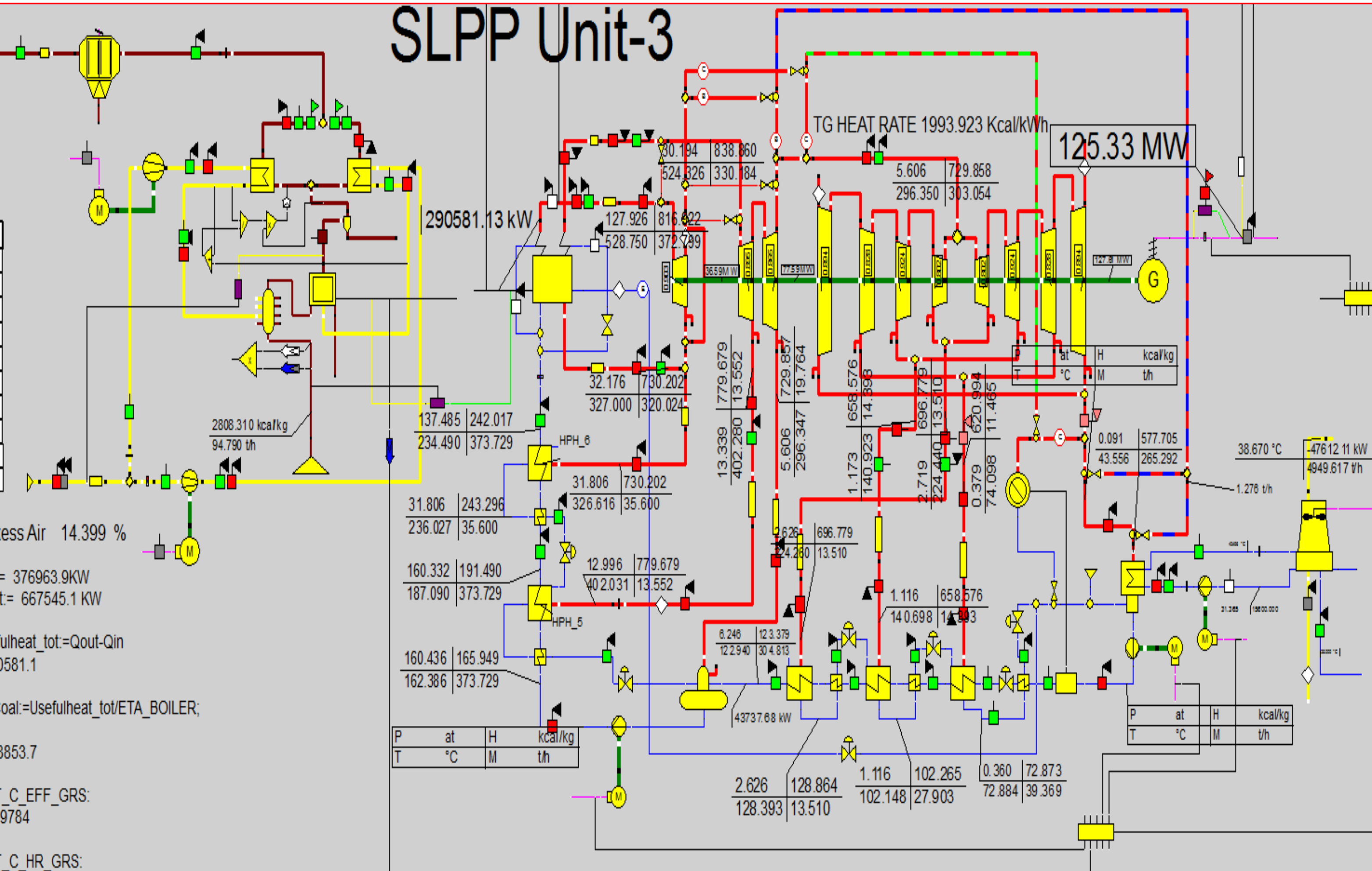
Heater Economy	
HEATER	TTD
HPH6	0.01 K
HPH5	-0.02 K
LPH3	2.97 K
LPH2	-0.27 K
LPH1	3.02 K
HEATER	DCA
HPH6	6.00 K
HPH5	3.56 K

Condenser	
KA	19475.9KW/K
TTD	4.7 K
LMTD	8.40K
Effectiveness	0.66
Cooling water fluid velocity	1.02 M/S
Effective cooling tube length	3.69 M

Turbine Economy	
Turbine	Efficiency
HPT Efficiency	89.61 %
IPT Efficiency	93.38 %
LPT Efficiency	89.45 %

Pump Economy	
PUMP	Efficiency
BFP Efficiency	80.00 %
CEP Efficiency	80.00 %

PG TEST Model



Heat Distribution	
Heat Rejected in Condenser	165.07 MW
Heat Used in HPH-6	21.96 MW
Heat Used in HPH-5	11.10 MW
Heat Used in LPH-3	9.33 MW
Heat Used in LPH-2	10.28 MW
Heat Used in LPH-1	7.31 MW
Heat Used in Drain Cooler + GSC	1.18 MW
Heat Used in Dearator	28.39 MW
Heat Remained in Condensate	15.44 MW
	270.06 MW

Plant Economy	
Gross power	125.3 MW
Net power	114.7 MW
Gross Efficiency	33.98 %
Net Efficiency	31.10%
UnitHeatRate(Gross)	2531.0 kcal/kWh
UnitHeatRate(Net)	2765.2 kcal/kWh
TGHeatRate(Gross)	1973.4 kcal/kWh
TGHeatRate(Net)	2156.0 kcal/kWh
Boiler Efficiency	78.78 %
Coal consumpt.	94.79 t/h

Exess Air 14.399 %

Qin:= 376963.9KW
Qout:= 667545.1 KW

Usefulheat_tot:=Qout-Qin
290581.1

Q_Coal:=Usefulheat_tot/ETA_BOILER;

368853.7

UNIT_C_EFF_GRS:
0.339784

UNIT_C_HR_GRS:
2531.0

UNIT_C_EFF_NET
0.311010

UNIT_C_HR_NET:
2765.2

AIR HEATER	
Seal Leakage	0.107450 %
Corrected Gas Out Temp	147.803112 °C
Efficiency	58.07 %
XRATIO	33.46 %

DATA for SAN-KEY Diagram	
TURBINE INPUT	345.4 MW
GENERATOR OUTPUT	125.33 MW
CONDENSER LOSSES	178.24 MW
OTHER LOSSES	41.85 MW

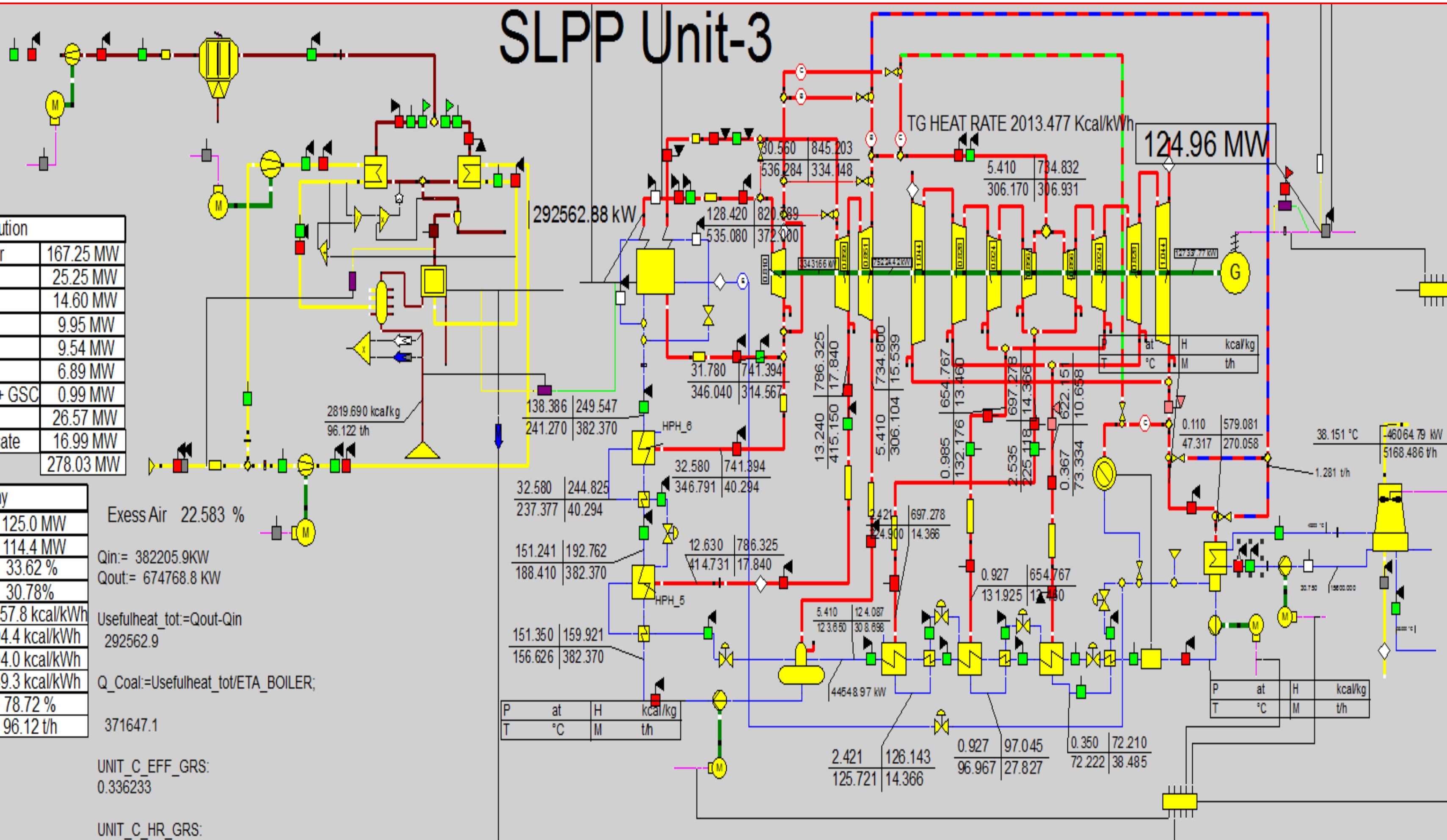
Heater Economy	
HEATER	TTD
HPH6	1.54 K
HPH5	3.61 K
LPH3	5.45 K
LPH2	5.29 K
LPH1	4.96 K
HEATER	DCA
HPH6	9.20 K
HPH5	1.48 K

Condenser	
KA	24995.0KW/K
TTD	3.1 K
LMTD	6.60K
Effectiveness	0.75
Cooling water fluid velocity	1.02 M/S
Effective cooling tube length	4.72 M

Turbine Economy	
Turbine	Efficiency
HPT Efficiency	90.29 %
IPT Efficiency	88.96 %
LPT Efficiency	88.42 %

Pump Economy	
PUMP	Efficiency
BFP Efficiency	79.84 %
CEP Efficiency	79.82 %

Operating Model



Heat Distribution	
Heat Rejected in Condenser	167.25 MW
Heat Used in HPH-6	25.25 MW
Heat Used in HPH-5	14.60 MW
Heat Used in LPH-3	9.95 MW
Heat Used in LPH-2	9.54 MW
Heat Used in LPH-1	6.89 MW
Heat Used in Drain Cooler + GSC	0.99 MW
Heat Used in Dearator	26.57 MW
Heat Remained in Condensate	16.99 MW
	278.03 MW

Plant Economy	
Gross power	125.0 MW
Net power	114.4 MW
Gross Efficiency	33.62 %
Net Efficiency	30.78%
UnitHeatRate(Gross)	2557.8 kcal/kWh
UnitHeatRate(Net)	2794.4 kcal/kWh
TGHeatRate(Gross)	2004.0 kcal/kWh
TGHeatRate(Net)	2189.3 kcal/kWh
Boiler Efficiency	78.72 %
Coal consumpt.	96.12 t/h

Exess Air 22.583 %

Qin:= 382205.9KW
Qout:= 674768.8 KW

Usefulheat_tot:=Qout-Qin
292562.9

Q_Coal:=Usefulheat_tot/ETA_BOILER;

371647.1

UNIT_C_EFF_GRS:
0.336233

UNIT_C_HR_GRS:
2557.8

UNIT_C_EFF_NET
0.307765

UNIT_C_HR_NET:
2794.4

AIR HEATER	
Seal Leakage	0.107450 %
Corrected Gas Out Temp	163.206485 °C
Efficiency	62.27 %
XRATIO	37.99 %

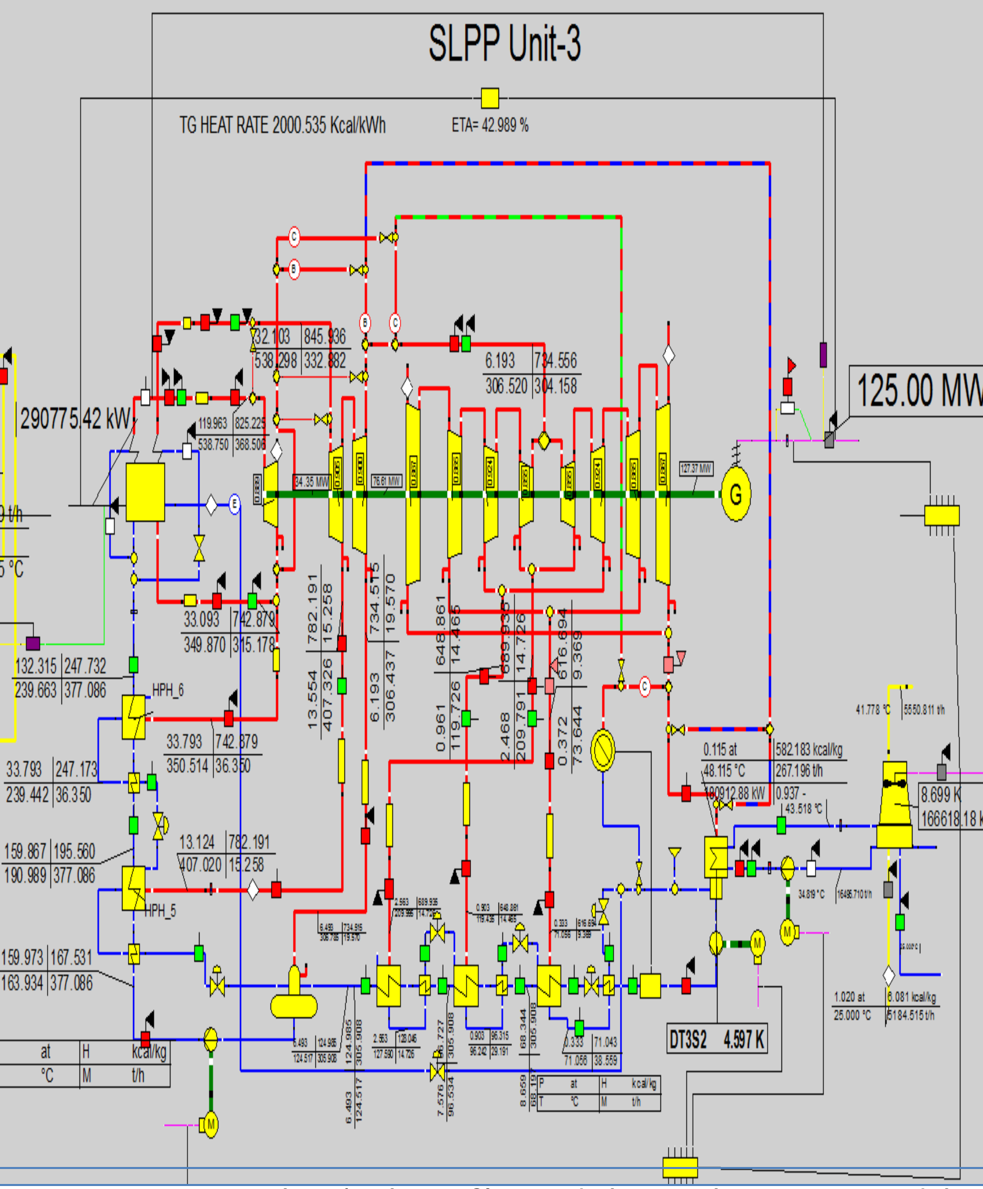
DATA for SAN-KEY Diagram	
TURBINE INPUT	346.3 MW
GENERATOR OUTPUT	124.96 MW
CONDENSER LOSSES	181.88 MW
OTHER LOSSES	39.47 MW

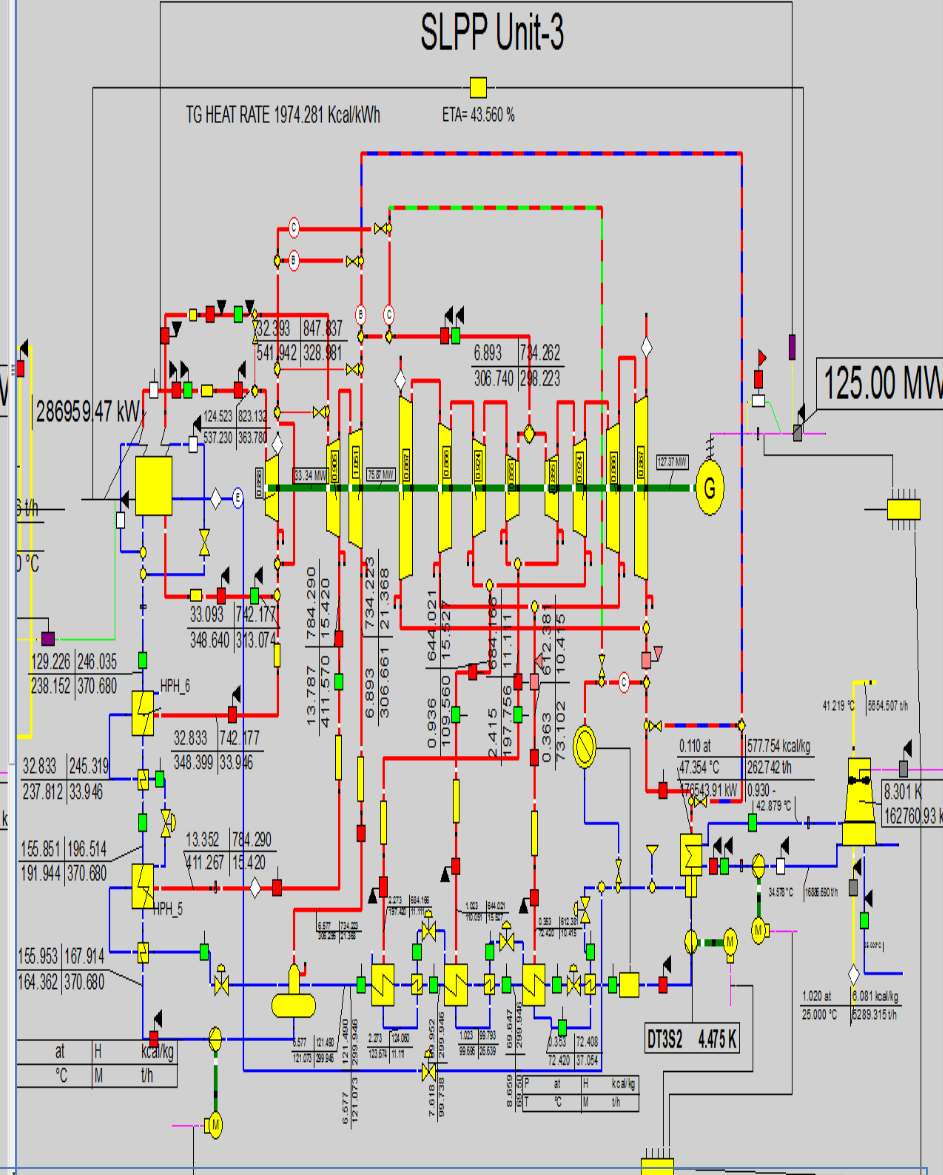
Heater Economy	
HEATER	TTD
HPH6	-3.89 K
HPH5	0.99 K
LPH3	2.07 K
LPH2	0.77 K
LPH1	2.54 K
HEATER	DCA
HPH6	10.45 K
HPH5	7.45 K

Condenser	
KA	14779.6KW/K
TTD	7.3 K
LMTD	11.32K
Effectiveness	0.56
Cooling water fluid velocity	1.02 M/S
Effective cooling tube length	2.80 M

Turbine Economy	
Turbine	Efficiency
HPT Efficiency	80.96 %
IPT Efficiency	86.70 %
LPT Efficiency	93.27 %

Pump Economy	
PUMP	Efficiency
BFP Efficiency	79.47 %
CEP Efficiency	79.61 %





On comparing the 'What-if' models analysis created by parameters captured before & after overhaul - an improvement of 6.98 milibar (5.23 mm of Hg) was found for the same load. This is equal to improvement of 7.61 Kcal/Kwh in GTHR. Condenser TTD also reduced from 5.55 to 3.70 at same load, CW Flow & inlet temperature which shows the reduced air ingress, cleaned tubes & no unwanted heating of condensate through HE drains passing. Overall heat rate of the unit also improved by 25 Kcal/Kwh.

Unit-1 AOH

Fans & Blowers Parameters for

Performance Analysis of

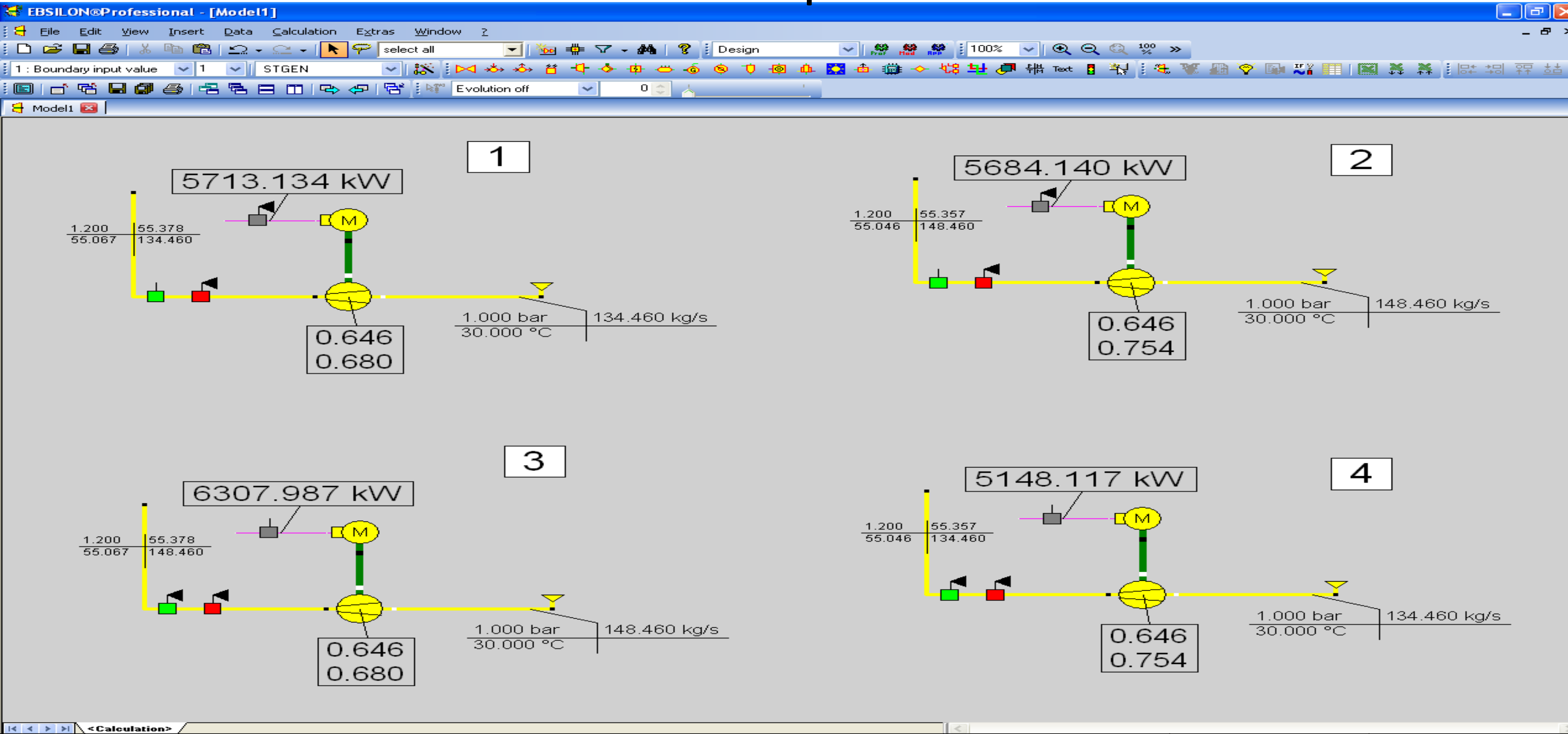
SA PH & PA PH Bottom Blocks

Tubes Replacement

DESCRIPTION	UNIT	Before AOH	After AOH
Load	MW	115.8	124.29
ID FAN - A MOTOR CURRENT	AMP	**80.16**	**73.48**
ID FAN - B MOTOR CURRENT	AMP	**80.63**	**76.48**
SA FAN - A MOTOR CURRENT	AMP	**80.51**	**78.95**
SA FAN - B MOTOR CURRENT	AMP	**72.71**	**81.45**
PA FAN - A MOTOR CURRENT	AMP	**86.14**	**85.8**
PA FAN - B MOTOR CURRENT	AMP	**90.79**	**85.86**
FBHE BLOWER - 1 MTR CURRENT	AMP	14.74	15.89
FBHE BLOWER - 3 MTR CURRENT	AMP	15.34	Standby
FBHE BLOWER - 1-3 MTR CURRENT	AMP	Standby	15.64
FBHE BLOWER - 2 MTR CURRENT	AMP	14.26	15.26
FBHE BLOWER - 4 MTR CURRENT	AMP	15.13	16.13
FBHE BLOWER - 2-4 MTR CURRENT	AMP	Standby	Standby
SEAL AIR BLOWER - 1 MTR CURRENT	AMP	19.05	20.44
SEAL AIR BLOWER - 2 MTR CURRENT	AMP	Standby	Standby
FBHE EC MAIN MTR CURRENT	AMP	18.51	Standby
FBHE EC STAND BY MTR CURRENT	AMP	Standby	19.6
PA FLOW EFFECTIVE	KG / S	49.75	50.15
PA HEADER PRESSURE	mbar	182.69	193.87
SA FLOW EFFECTIVE	KG / S	72.51	86.72
SA HEADER PRESSURE	mbar	79.71	79.49
TOTAL AIR FLOW	KG / S	**134.46**	**148.46**

Calculation of Power Saving using EBSILON

PAPH & SAPH Bottom Blocks Tubes Replacement Work in Unit-1 AOH 2013



Conclusion from EBSILON exercise	Before	After	Unit
TOTAL AIR FLOW (Kg/s)	134.46	148.46	Kg/sec
Total Amps of all fans & blowers (Amps)	588	585	Amp
Total Power Consumption of Fans & Blowers	5713.19	5684.14	KW
power requirement to deliver 148.46 Kg/S air flow with leaking Tubes condition	---	6307.99	KW
power requirement to deliver 134.46 Kg/S air flow with improved tubes condition	5148.12	---	KW
Net Saving in KW considering same CONDITIONS as above	536.02	594.8	KW
Average Annual Saving considering 330 days of Unit running	44.78 Lakhs Kwhr		

SLPP Unit-2 Cooling Tower Effectiveness Measurement Test Results

Before Fills Replacement (Test Carried Out on 4/05/2012 time : 15:00 to 16:30Hrs)

Hot Water Temperature **44.5** taken at CT Risers

CT Fan No.	CT Fan Amp	WBT-DMP Side	WBT-Canteen Side	Fills Area-DMP Side Avg	Fills Area-Canteen Side Avg	Cold Water Temp - Canteen Side(Avg)	Cold Water Temp -DMP Side(Avg)	Approach DMP Side	Approach Canteen Side Side	Cold Water Temp -DMP Side(Max)	Cold Water Temp - Canteen Side(Max)	Cooling Range DMP Side	Cooling Range Canteen Side Side	Effectiveness DMP Side	Effectiveness Canteen Side Side
2 / 1	49	26	28.5	41.5	40.5	34.52	34.1	8.1	6.02	35.3	35.8	10.4	9.98	56.22	62.38
2 / 2	37	26.5	27.8	40.7	42.1	35.32	35.3	8.8	7.52	36.6	37.3	9.2	9.18	51.11	54.97
2 /3	50	26.5	27	40.1	40	35.75	34	7.5	8.75	35.8	37.2	10.5	8.75	58.33	50.00
2 / 4	53	27	26	41.3	40.8	35.35	35.1	8.1	9.35	35.6	37.1	9.4	9.15	53.71	49.46
2 / 5	55	27	26	39.3	41.4	35.45	35	8	9.45	36	37.3	9.5	9.05	54.29	48.92
2 /6	41	26.5	27.5	42.8	41.9	35.65	34.3	7.8	8.15	35.2	37.1	10.2	8.85	56.67	52.06
2 / 7	46	27	28	42.3	42.9	36.8	34	7	8.8	35	37.9	10.5	7.7	60.00	46.67
2 / 8	38	27	28	39.7	43.1	37	34.1	7.1	9	34.4	38.6	10.4	7.5	59.43	45.45
2 /9	50	26.5	27.5	41	42.6	36.4	33.7	7.2	8.9	34.2	38.2	10.8	8.1	60.00	47.65
Average		**26.7**	**27.4**	**41.0**	**41.7**	**35.8**	**34.4**	**7.7**	**8.4**	**35.3**	**37.4**	**10.1**	**8.7**	**56.6**	**50.8**

Remark: Reading are taken with Thermal Imager (Testo 8800). Ct Fan no 4,5,6,8,9 DM Plant side - most of the fills area found in dry condition, no water flow was there. Water flow through fills at canteen side found more than DM plant side, so flow distribution (DM Plant side nozzles OR Fills) needs checking.

After Fills Replacement (Test Carried Out on 16/09/2013 time : 14:59 to 15:22 Hrs)

Unit Avergae Load	104	MW
CW Inlet Temperature	36	DegC
CW Outlet Temperature	45	DegC
Condenser Back-Pressure	125	mbar

WMS Reading	
Humidity online-	59.74
Dry bulb temp-	33
Wet bulb temp-	25

CT Fan No.	CT Fan Amp	Riser Temp		Wet Bulb Temp		Fills Area				Cold Water Pond				Approach		Cooling Range		Effectiveness %		RH% at inlet of CT Cells	
		Max	Avg	Main Road Side	Plant Side	Main Road Side		Plant Side		Main Road Side		Plant Side		Main Road Side	Plant Side	Main Road Side	Plant Side	Main Road Side	Plant Side		
						Max	Avg	Max	Avg	Max	Avg	Max	Avg	With Max Riser Temp							
Front	---	---	---	29.44	28.33	37.72	32.92	---	---	35.84	34.04	---	---	5.50	---	6.96	---	55.88	---	65.5	80.3
1 / 1	47.3	41.9	40.9	29.44	29.4	38.30	31.28	42.0	35.9	33.48	31.84	36.3	34.4	3.22	5.9	9.2	6.5	74.18	52.51	65.5	73
1 / 2	53.3	42	41	30.00	31.7	38.54	32.78	41.5	36.7	34.28	32.36	36.4	34.8	3.32	3.9	8.7	6.4	72.33	61.94	65.7	78
1 / 3	49.3	42.5	41.5	29.44	32.2	39.96	33.02	42.7	37.6	34.98	32.96	36.7	35.1	4.53	3.6	8.5	6.6	65.34	64.51	66	75
1 / 4	49.3	42.7	41.8	29.44	32.8	38.46	32.72	43.7	38.0	34.78	33.10	37.2	35.3	4.50	3.4	8.8	6.5	66.09	65.41	62.5	79.5
1 / 5	50.0	43.2	42.2	28.89	32.8	40.04	32.76	43.0	37.9	34.96	32.76	37.1	35.0	4.97	3.3	9.3	7.2	65.26	68.60	59	85
1 / 6	51.3	43.2	42.3	28.89	31.7	40.56	32.44	44.3	38.6	34.16	32.54	36.8	34.7	4.46	4.0	9.9	7.5	68.83	64.94	59	82
1 / 7	55.0	43.4	42.4	28.89	31.1	40.82	33.20	40.4	35.2	35.26	33.00	36.1	33.9	5.24	3.9	9.3	8.4	63.88	68.35	62.5	73
1 / 8	49.0	43.2	42.3	28.89	31.1	40.48	31.10	40.5	33.8	33.84	32.30	34.6	33.2	4.18	2.8	10.1	9.3	70.78	76.76	62.5	74.5
1 / 9	52.3	43.3	42.4	28.89	30.6	38.26	32.22	39.6	34.9	34.48	32.58	34.9	33.4	4.64	3.6	9.8	9.1	67.79	71.64	59	71.5
Rear				29.44	30			37.50	32.54			34.02	32.30	---	2.60	---	10.14	---	79.56	62.5	68.5
Average		**42.82**	**41.87**	**29.20**	**31.48**	**39.31**	**32.44**	**41.51**	**36.12**	**34.61**	**32.75**	**36.01**	**34.20**	**4.45**	**3.72**	**9.29**	**7.50**	**68.28**	**66.07**	**62.7**	**76.4**

Remark: Reading are taken using Thermal Imager (Testo 8800) instrument. Fills Area Temp (Max) is an indication of choked up fills / nozzles. Average Relative Humidity during the test period – 69.5% (59% to 85%). Cooling Tower Effectiveness derived from DCS values & data taken from Weather Monitoring System is 61.16%. Lower values of Effectiveness as per measurement carried out in the vicinity of cooling tower is due to effect of higher humidity of recirculating air. SSF was not in service .

SLPP Unit-2 Cooling Tower Effectiveness – Normalization of Test Results with Atmospheric Condition

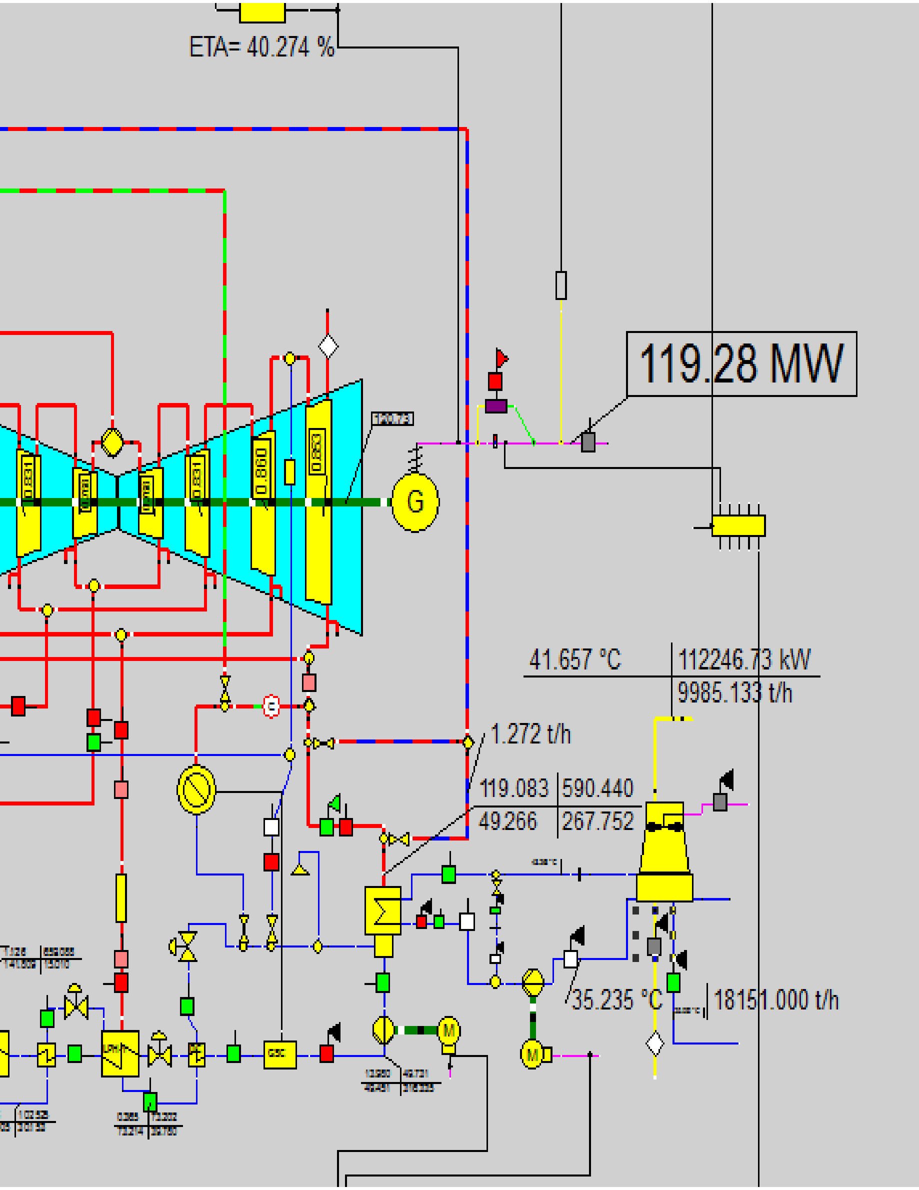
Sr. No.	Particulars	Value	Unit
1	Rise in Average WBT After & Before CT Fills Replacement 30.34 - 27 =	3.34	Deg C
2	Average Cold Water Temperature before CT Fills Replacement	35.1	Deg C
3	Nullifying the effect of Season on WBT As it is increased by 3.34 Deg. C, The Average Cold Water Temperature before CT fills replacement with increased WBT would be	38.4	Deg C
4	Average Cold Water Temperature After CT Cell refurbishment	34.4	Deg C
5	Net Improvement after CT Cells Fills Replacement	4.1	Deg C

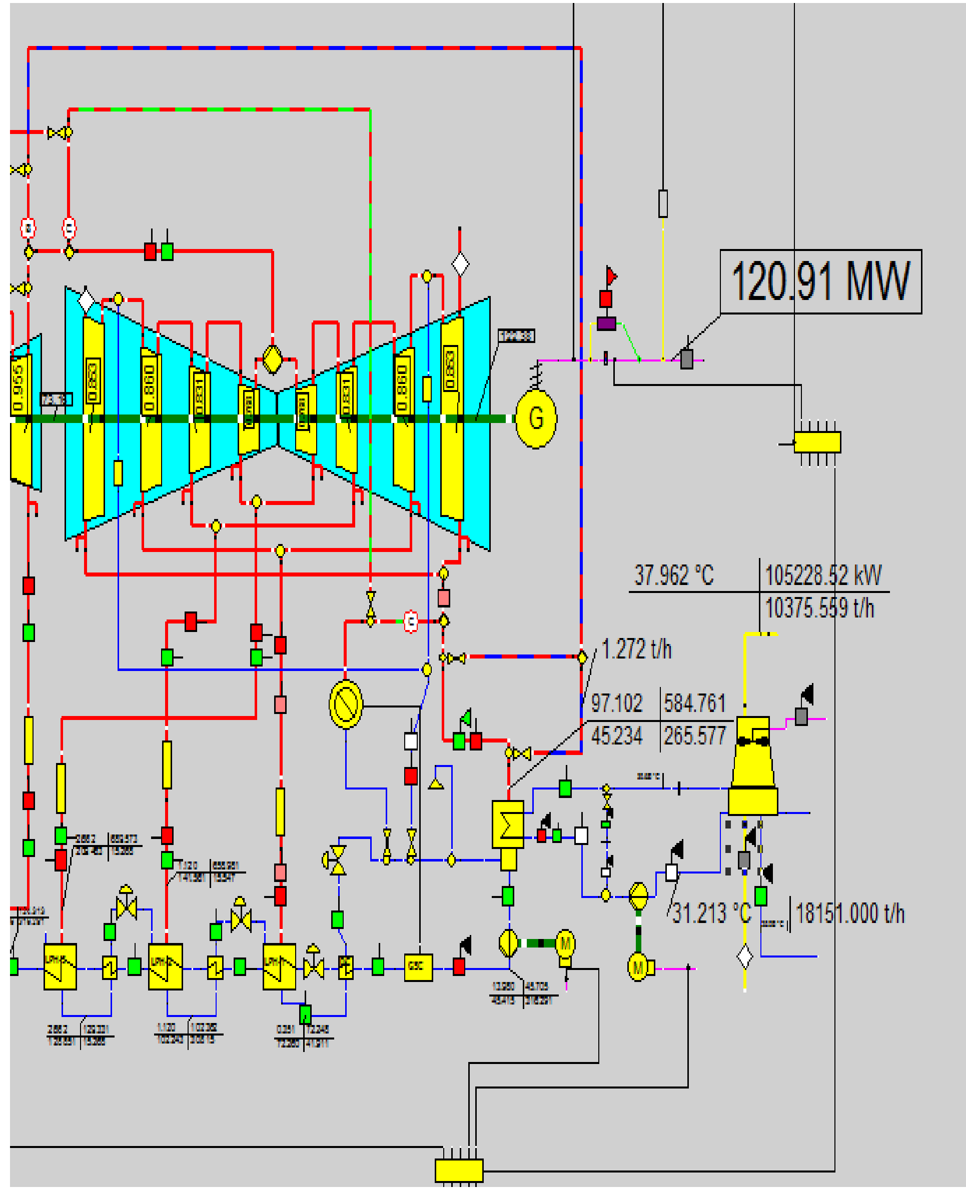
After the fills replacement work was completed in one cell, effectiveness test was carried out & based on on the test result, total improvement was envisaged at 3.7 Deg C in CW outlet temp. Using Ebsilon, we could be able to analyze how much load increment is possible with condenser vacuum improvement – as evident from the EBS snapshots in next slide, approx 1.7 MW rise was found.

After the fills replacement work was completed in all cells, total improvement of 4.1 deg in CW inlet temp was found , which is equivalent to increase in unit load by 1.7 MW, reduction in GTHR by 28 kCal/kWh and improvement in Condenser Vacuum by 26mBar .

SLPP Unit-2 Cooling Tower Effectiveness — Before Fills Replacement Work

Effect of High CW inlet temperature on Generated Power Using EBSILON





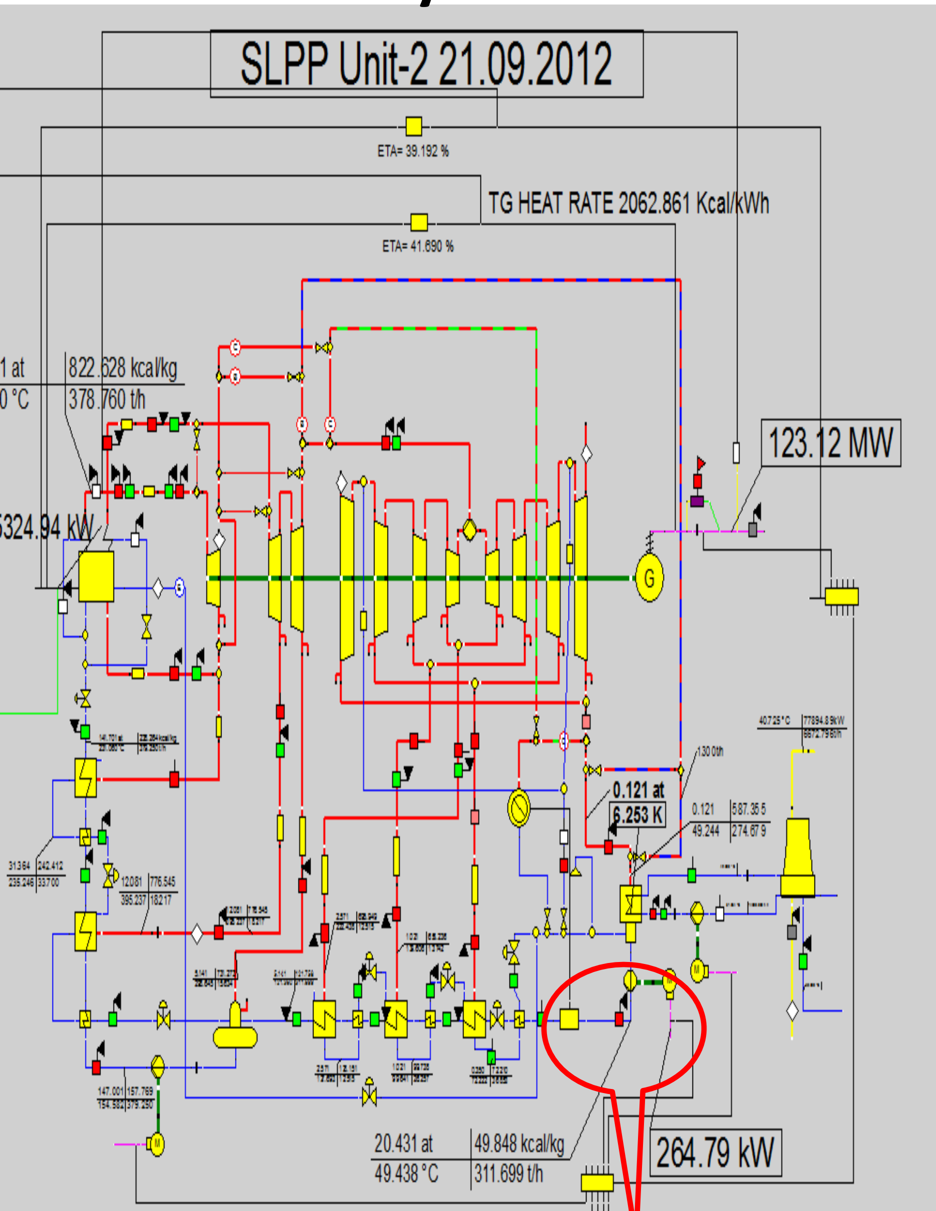
LOAD	Cond BackPress	Cond BackPress	Cond Vacuum	per MW Change	per MW Change
MW	mbar	Kg/cm2	Kg/cm2	Kg/cm2	MMWCL
130	97.44417	0.09937	0.90063	0.00044	4.41
129	97.01137	0.09892	0.90108	0.00044	4.41
128	96.57938	0.09848	0.90152	0.00044	4.40
127	96.14819	0.09804	0.90196	0.00044	4.39
126	95.71781	0.09760	0.90240	0.00044	4.38
125	95.28824	0.09717	0.90283	0.00064	6.38
124	94.66287	0.09653	0.90347	-0.00032	-3.21
123	94.97788	0.09685	0.90315	0.00071	7.09
122	94.28247	0.09614	0.90386	0.00044	4.37
121	93.85415	0.09570	0.90430	0.00044	4.36
120	93.42665	0.09527	0.90473	0.00087	8.69
118	92.57475	0.09440	0.90560	0.00086	8.65
116	91.72651	0.09353	0.90647	0.00086	8.62
114	90.88150	0.09267	0.90733	0.00086	8.58
112	90.03969	0.09181	0.90819	0.00085	8.55
110	89.20124	0.09096	0.90904	0.00085	8.51
108	88.36662	0.09011	0.90989	0.00085	8.48
106	87.53510	0.08926	0.91074	0.00084	8.45
104	86.70664	0.08842	0.91158	0.00084	8.41
102	85.88177	0.08758	0.91242	0.00084	8.37
100	85.06048	0.08674	0.91326	0.00083	8.34
98	84.24218	0.08590	0.91410	0.00083	8.30
96	83.42813	0.08507	0.91493	0.00080	7.95
94	82.64806	0.08428	0.91572	0.00079	7.93
92	81.87064	0.08348	0.91652	0.00080	8.00
90	81.08640	0.08269	0.91731	0.00081	8.13
88	80.28898	0.08187	0.91813	0.00081	8.10
86	79.49482	0.08106	0.91894	0.00081	8.08
84	78.70267	0.08025	0.91975	0.00081	8.05
82	77.91281	0.07945	0.92055	0.00080	8.03
80	77.12554	0.07865	0.92135	0.00080	8.01
78	76.34013	0.07785	0.92215	0.00080	7.98
76	75.55740	0.07705	0.92295	0.00080	7.96
74	74.77668	0.07625	0.92375	0.00079	7.94
72	73.99819	0.07546	0.92454		
Average Reduction required Below 120 MW					**8.25**

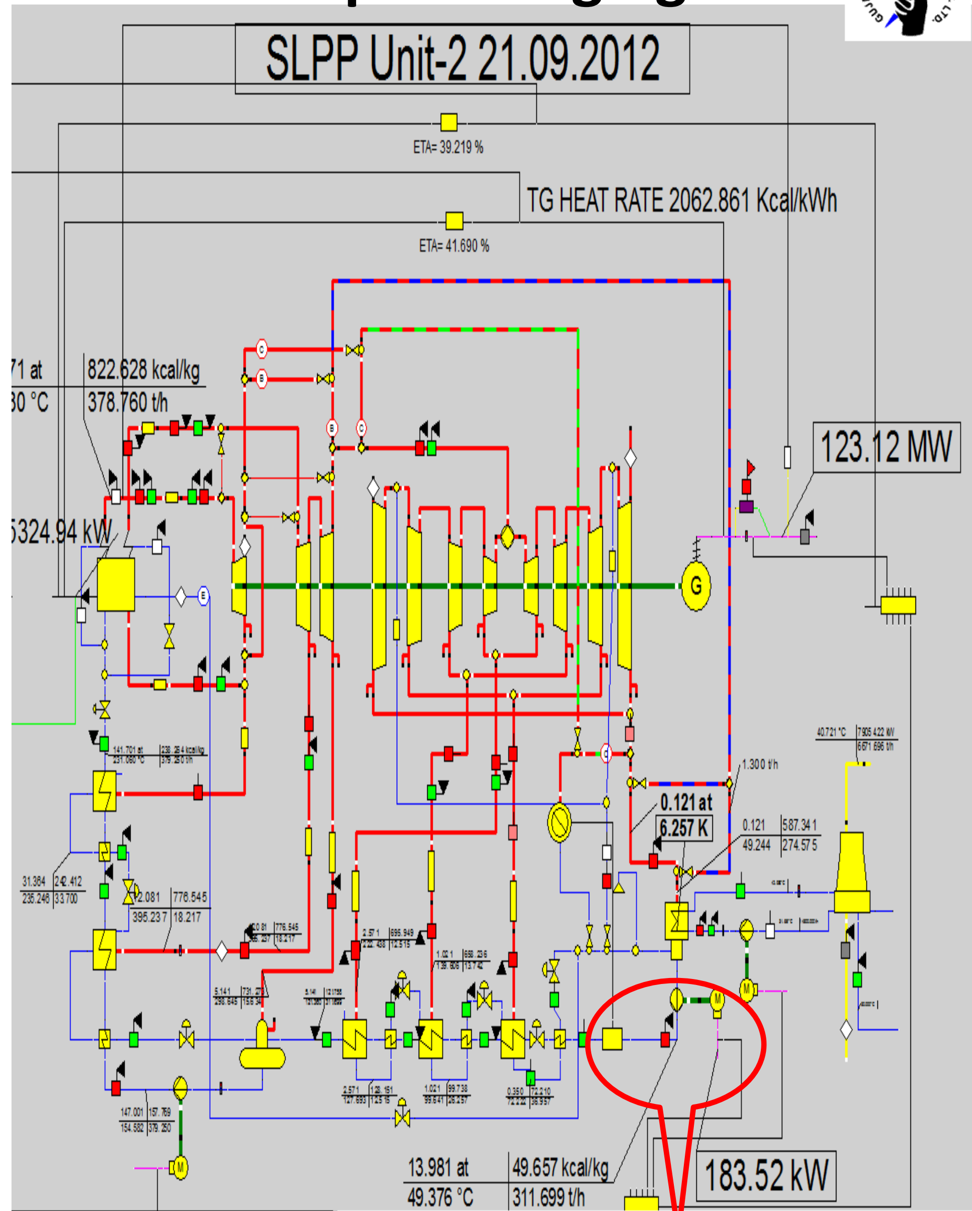
Relation between MW & Condenser Back Pressure Generated for Phase-I Units

When we reduce load by one MW, condenser vacuum gets increased by average 8.25 MMWCL. This relation is useful to Plant Operators in deciding optimum vacuum* while reducing load & no of CT fans to be stopped

*OEM has not provided the required curve

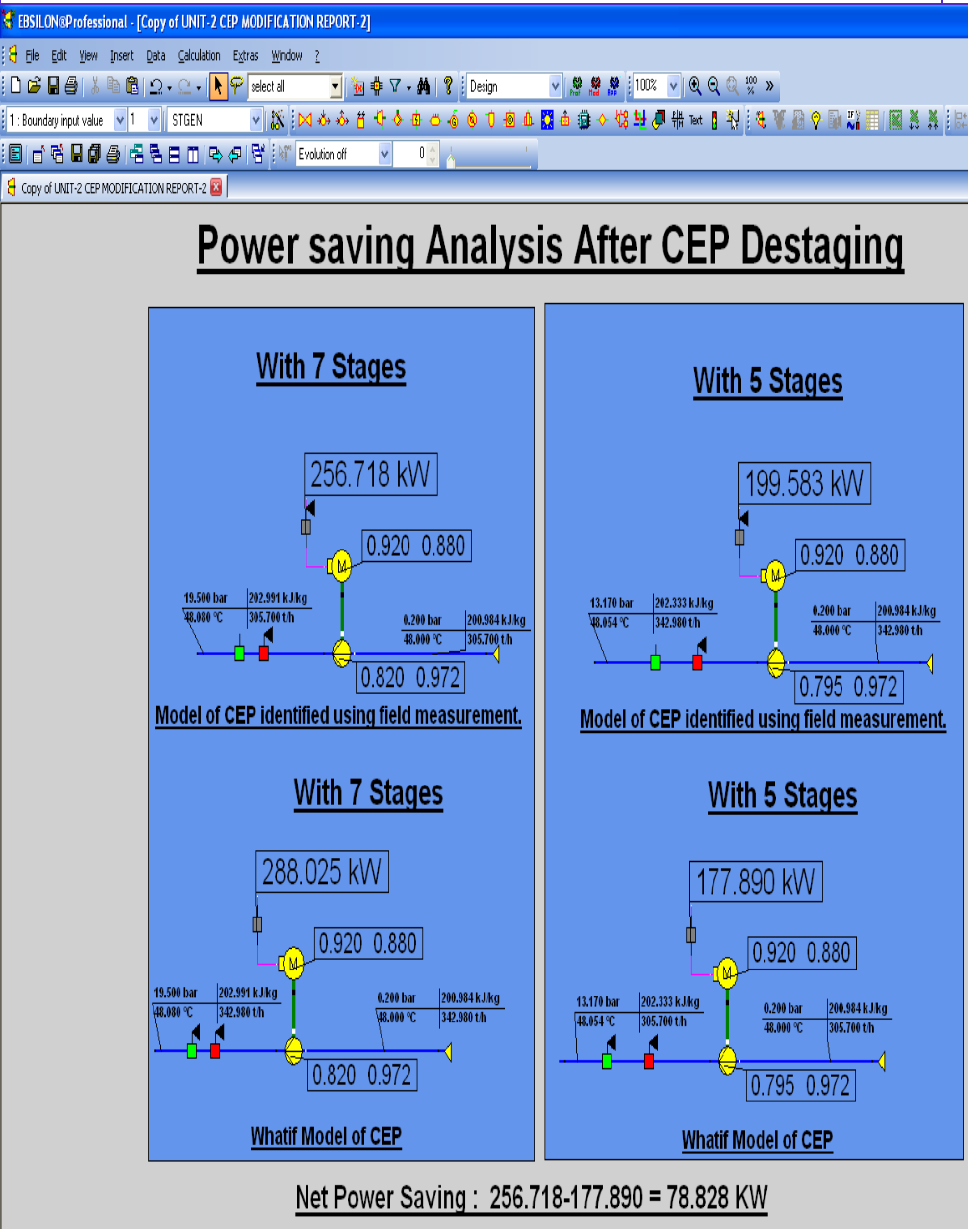
Study of Condensate Extraction Pump De-staging

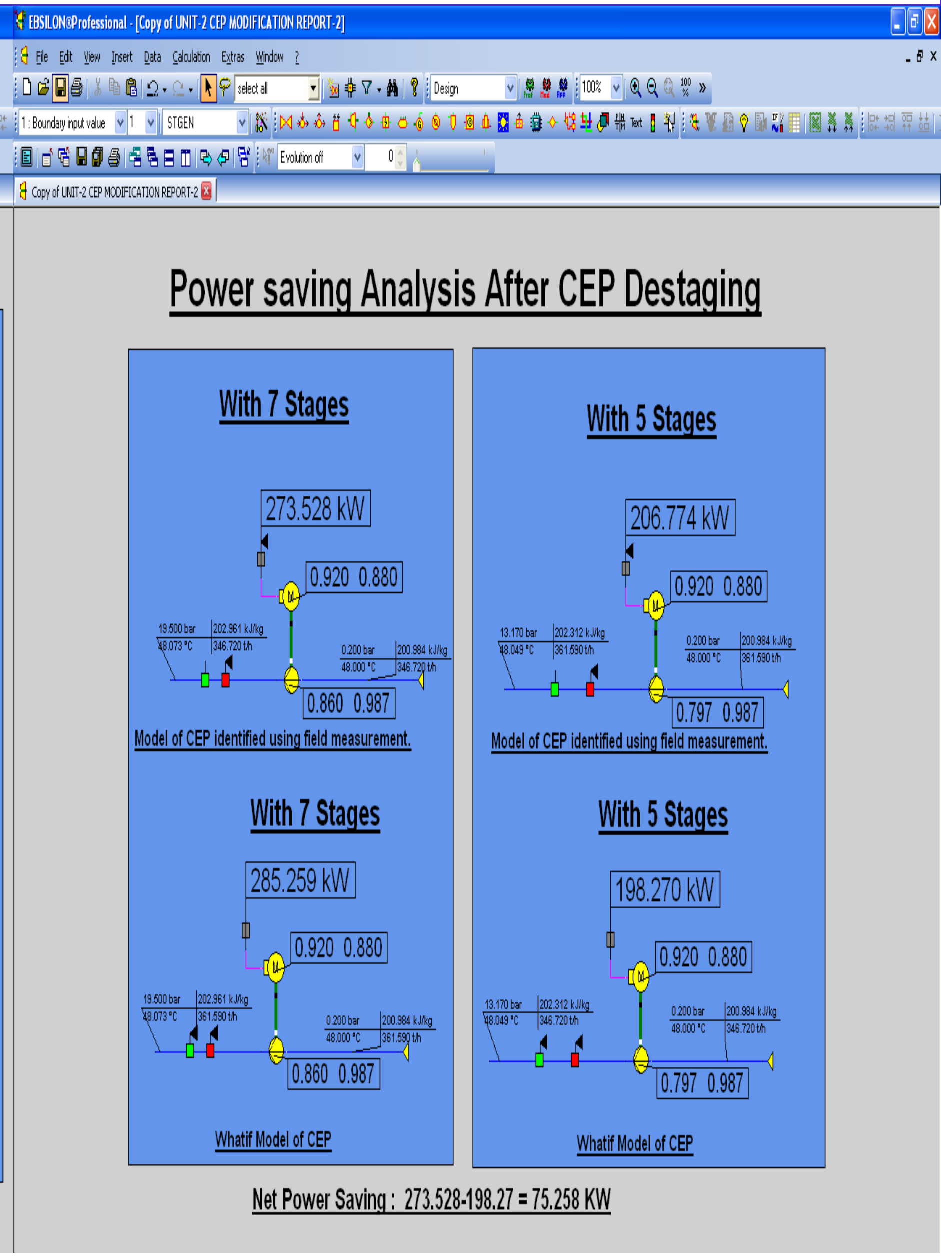




On Reducing CEP Discharge Pressure - "No Change, No Error, No warning" displayed by Ebsilon model of the Unit : This encouraged us to go ahead with the idea.

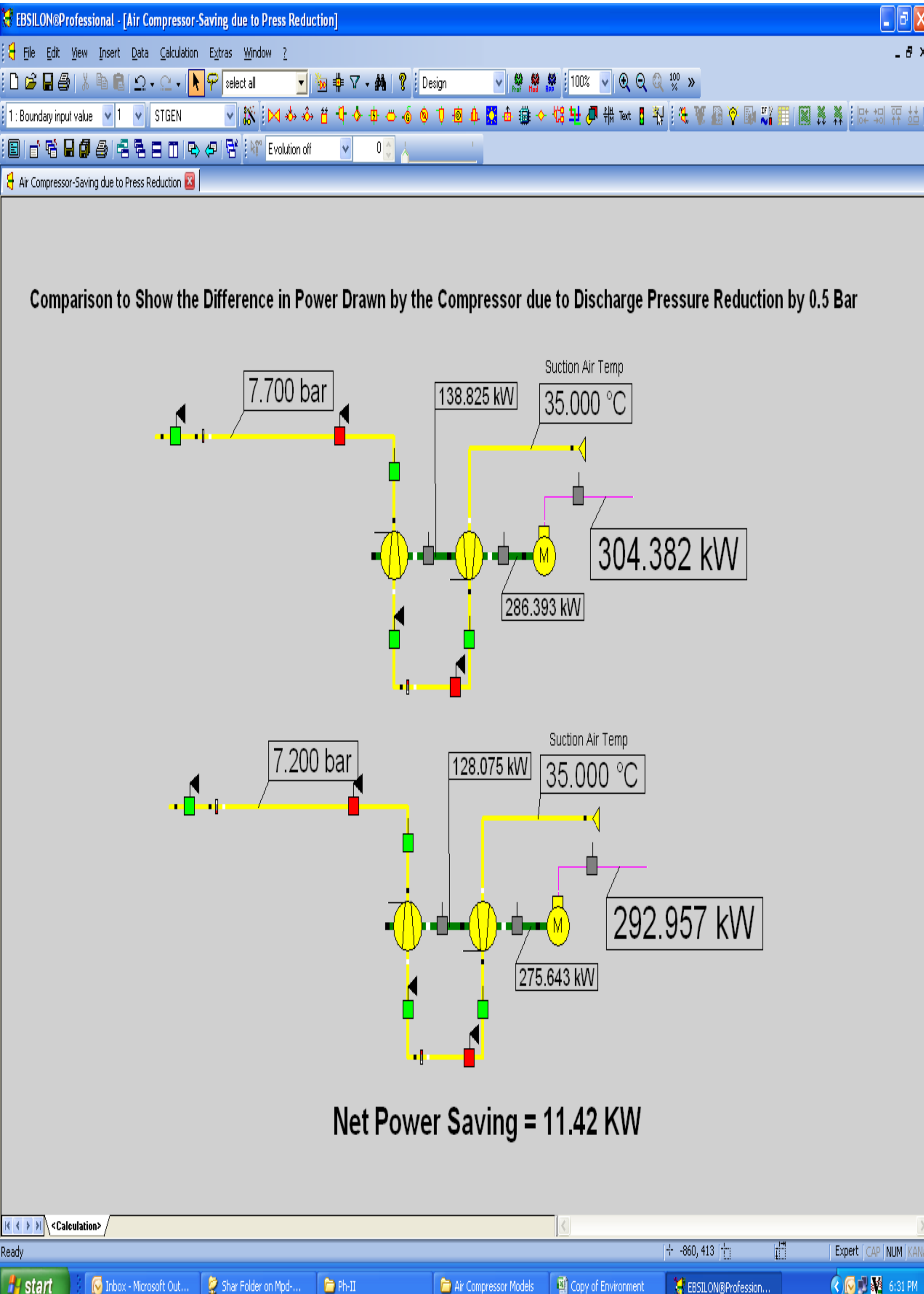
Power Saving Achieved in SLPP Unit-1	Power Saving Achieved in SLPP Unit-2

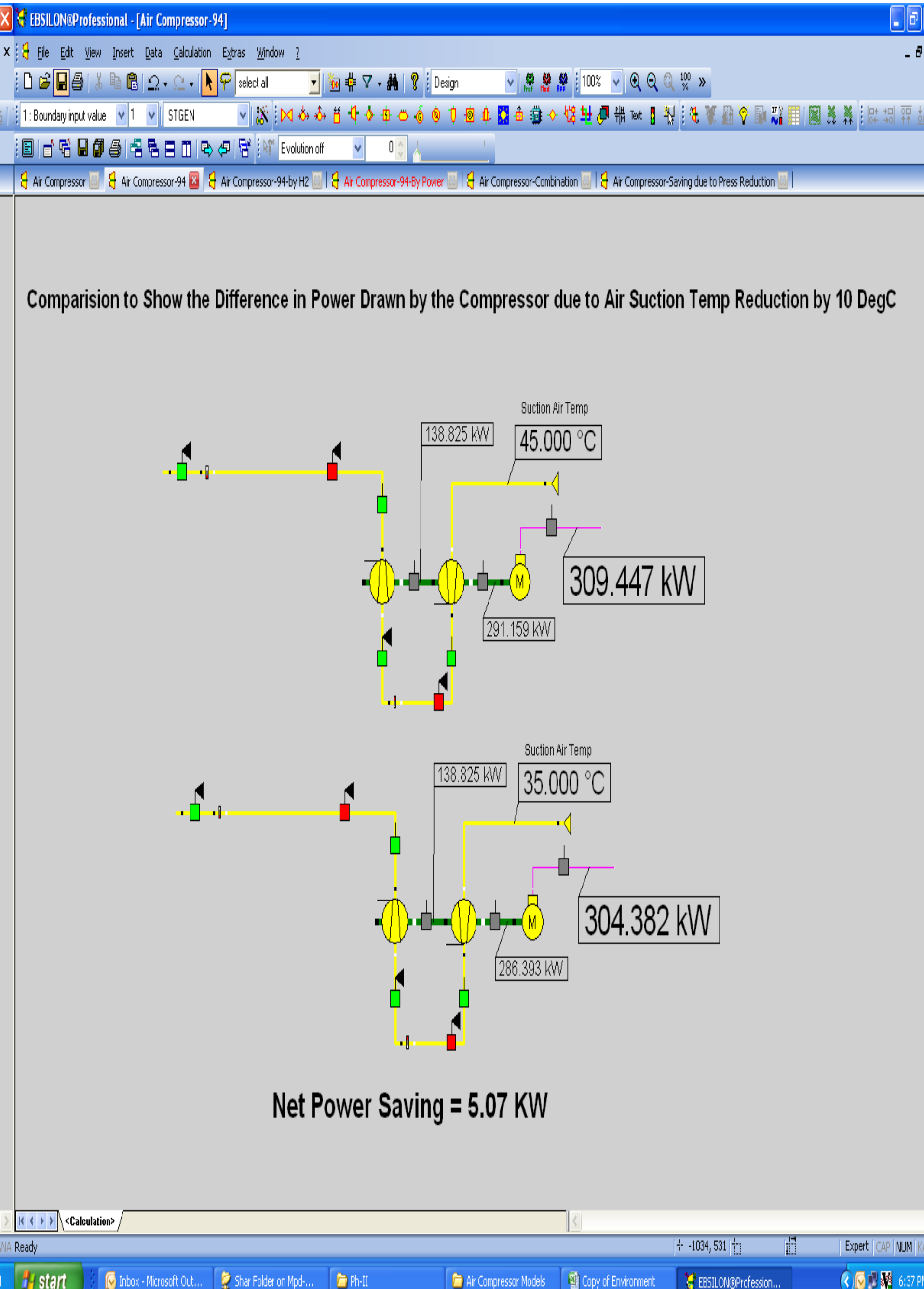




Total Saving Achieved in both Unit: 75.258 + 78.828 = 154.01 KW (Annual Saving – 12.204 Lacs KWhr

Power Saving Calculation using EBSILON in Air Compressors





Utilization of Bed Ash Heat Drained out of Combustor in LPH Circuit
An innovative Idea under Study

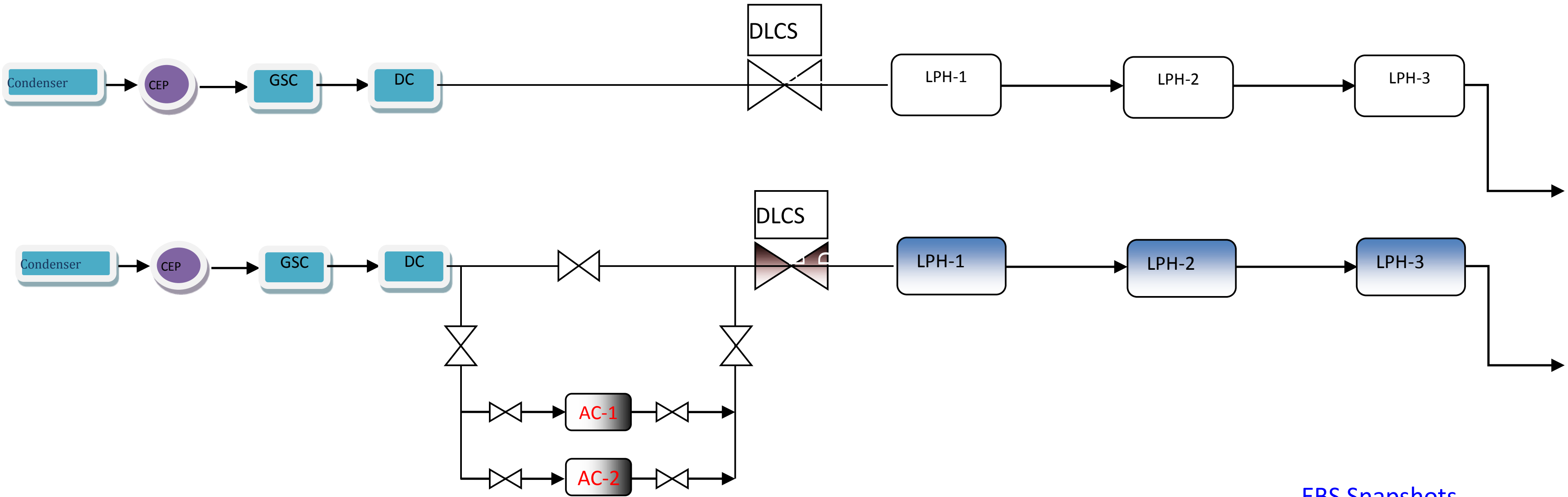
Introduction: To maintain combustor fluidization in healthy condition, it is necessary to drain out the ash from the combustor when its DP is increased. This is called 'Bed Ash'. Bed ash is drained at very high temperature of 850^{O}C & it contains large amount of heat. Every time ash is unloaded, a portion of heat is recovered through vents of ash coolers connected with combustor. Still lot of heat is going as waste through cooling water circuit.

Ash coolers are the boiler auxiliary situated at zero meter, below combustor. There are two ash coolers having three chambers per ash cooler, with refractory lined walls. They are provided with cooling coils carrying ACW (DM) water and fluidizing air fed from the bottom through nozzles to keep hot ash in fluidizing state. This in turn results in cooling of ash unloaded from the combustor time to time. The hot air vented out to the combustor and the cold ash finally unloaded in Bed Ash Conveyor.

Present Scenario: Bed ash is being cooled in Ash Coolers with the help of ACW, which in turn getting cooled by CCW system and huge amount of heat is going waste through cooling tower via CCW system.

Proposal: It is proposed to use condensate water in place of ACW (DM) water to recover the heat in of bed ash, drained from the combustor into ash cooler. Condensate water is to be tapped after DC before entering to LPH-1 and circulating it through ash cooler.

How it will work: Diverted condensate through ash cooler will enter LPH-1 after getting heated in ash cooler. As the temp of condensate will rise, the condensation of steam sucked from LPT will be reduced & flow of steam extraction from LPT to LPH-1 will start reducing and this extra steam will be diverted towards LPT exhaust subsequently will produce more power. This is the main advantage. This scheme has many more secondary advantages.



EBS Snapshots

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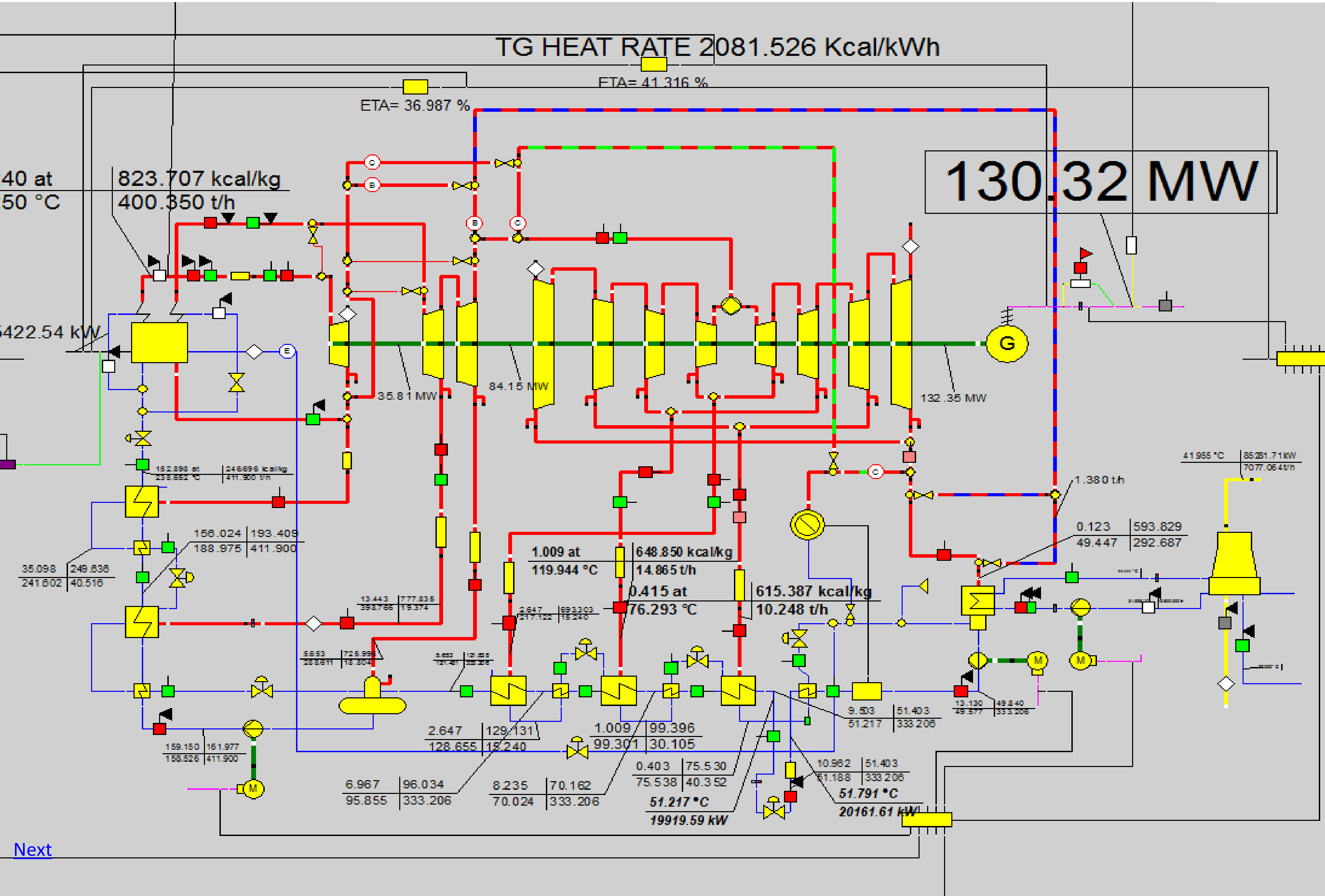

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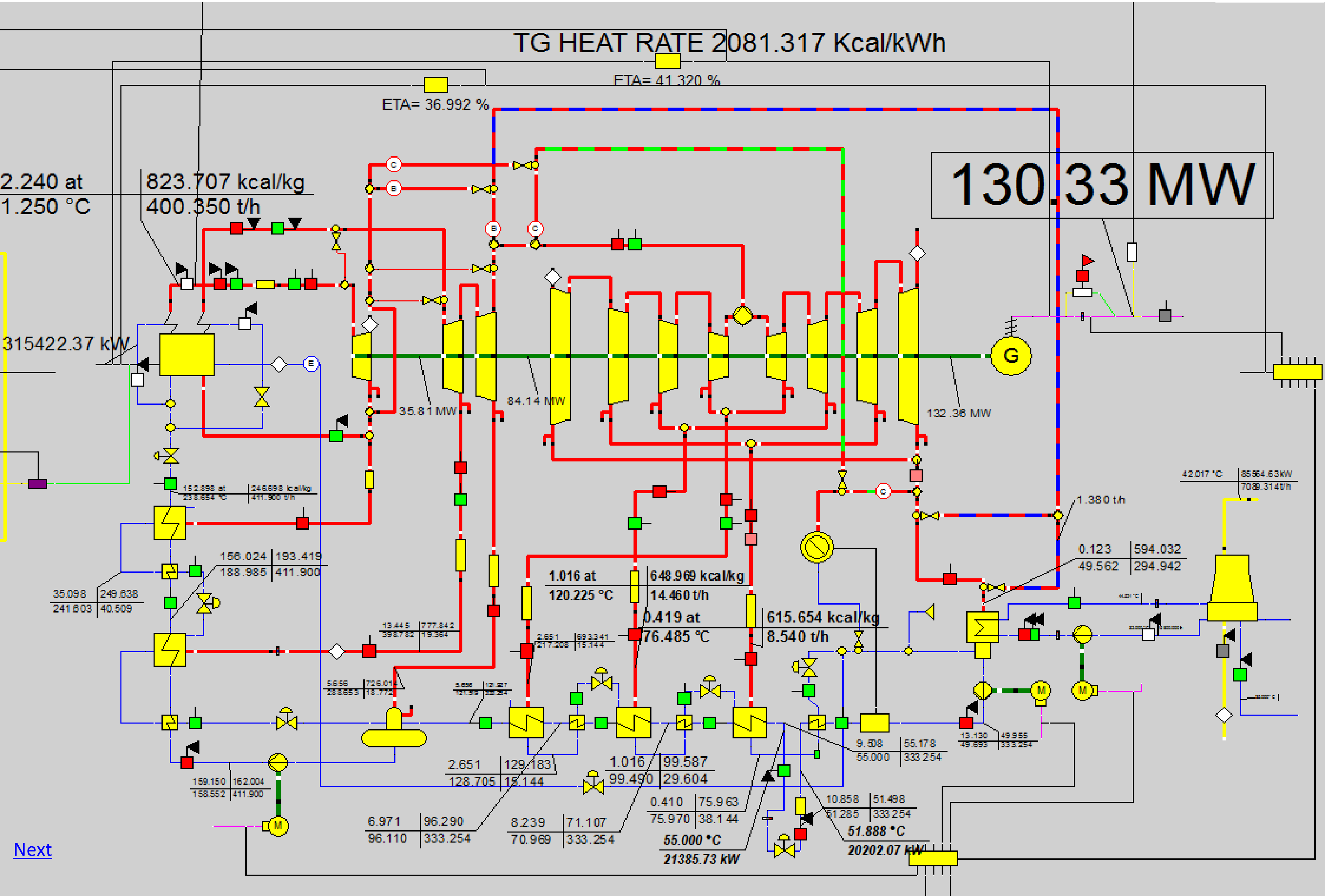

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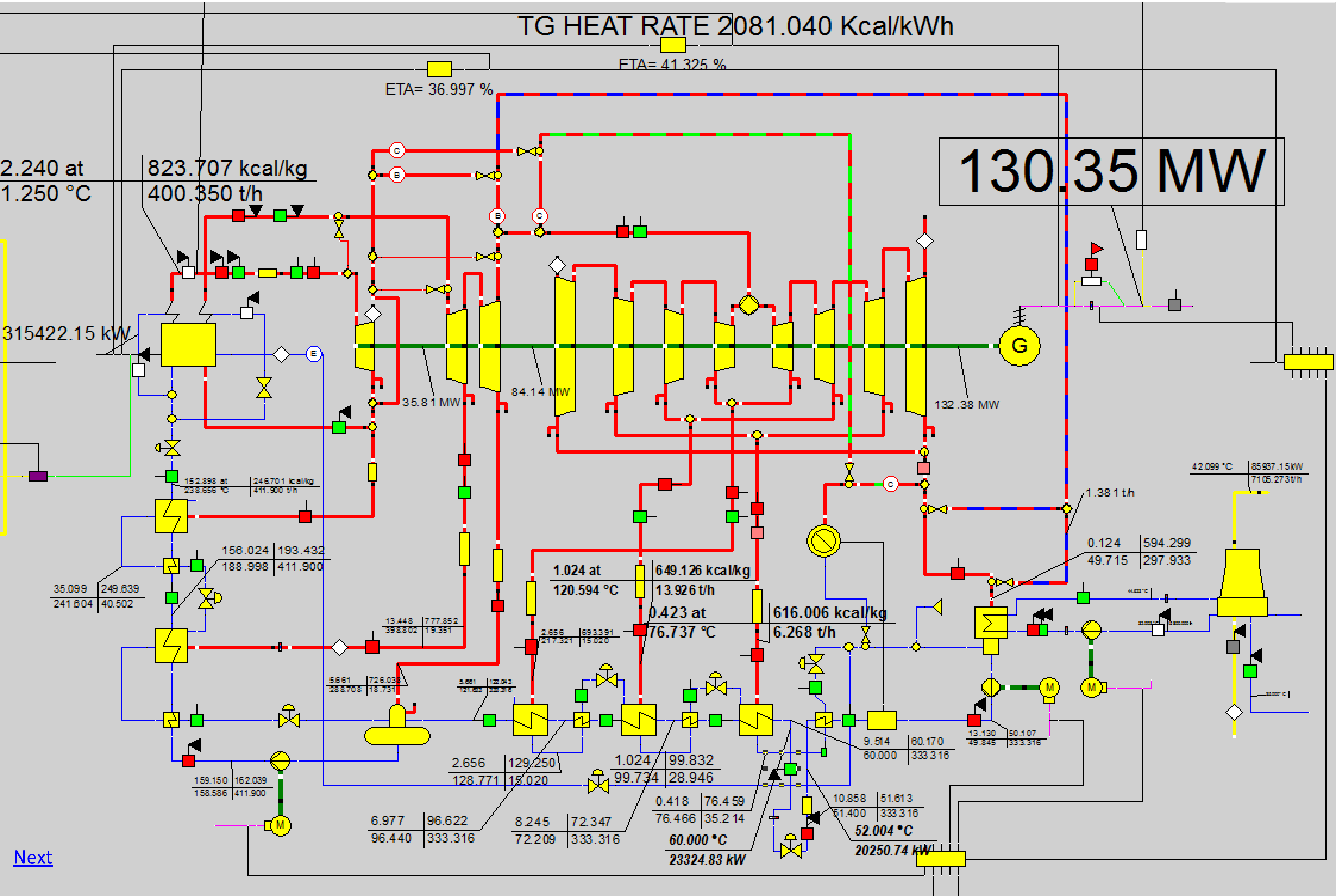

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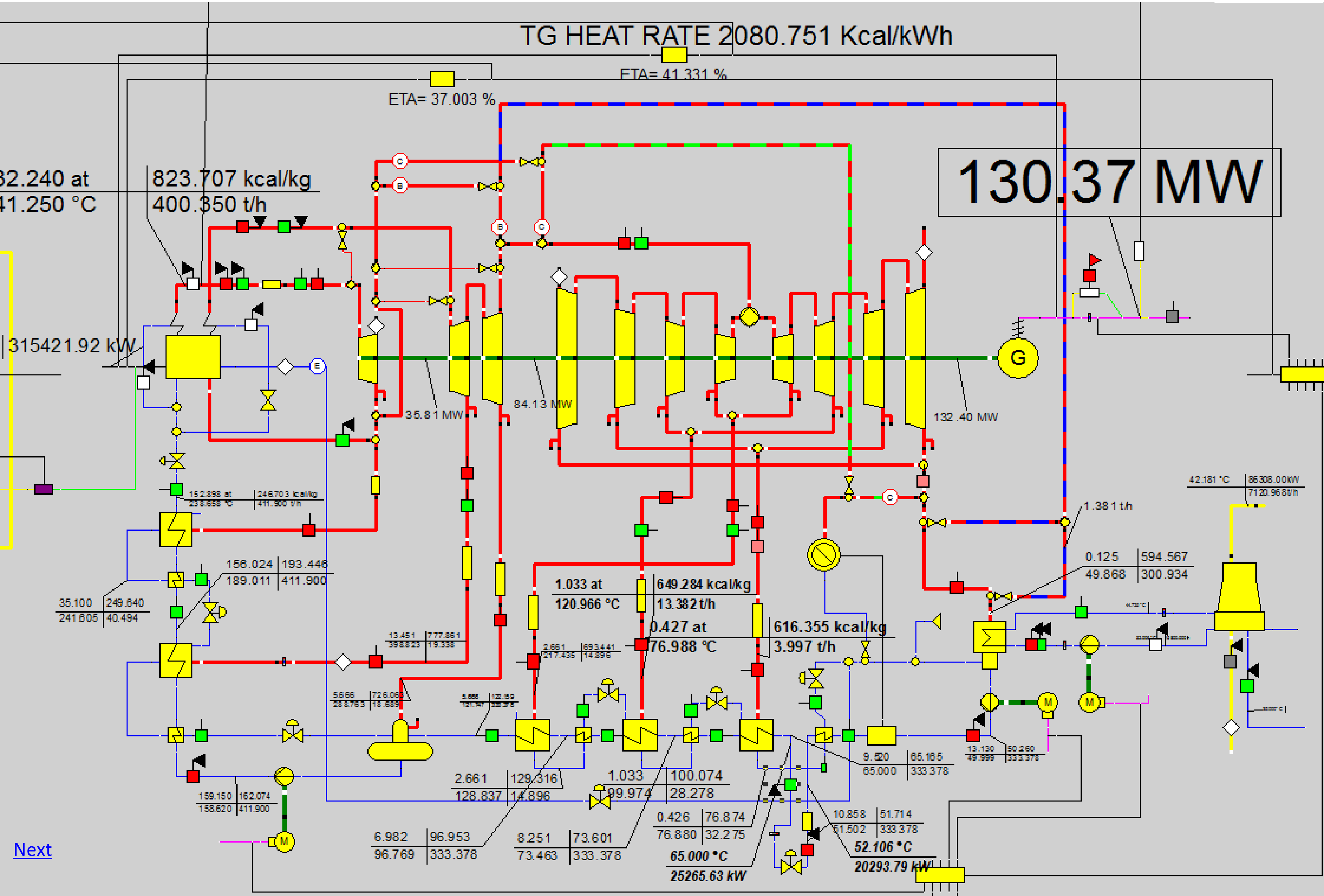

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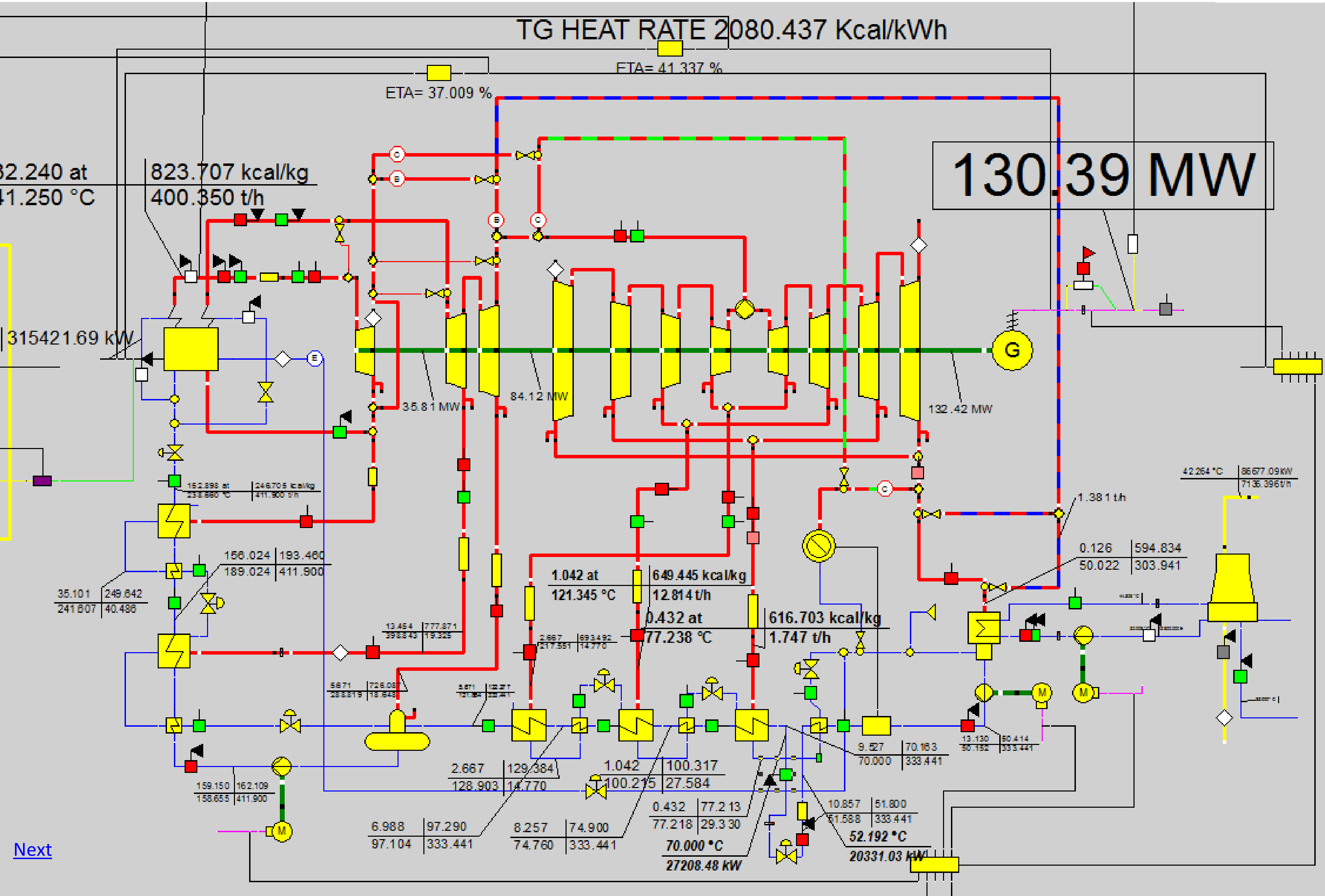

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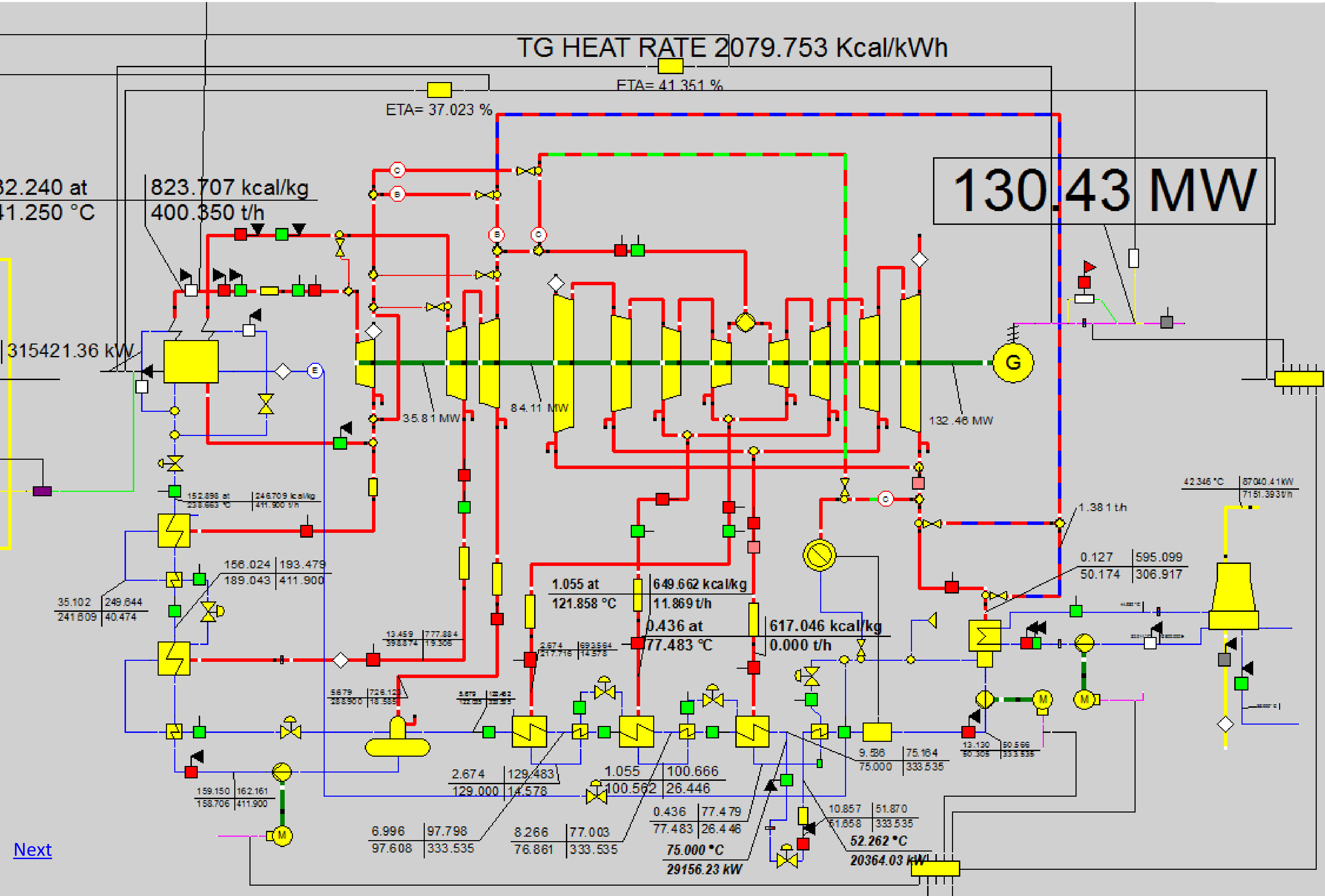

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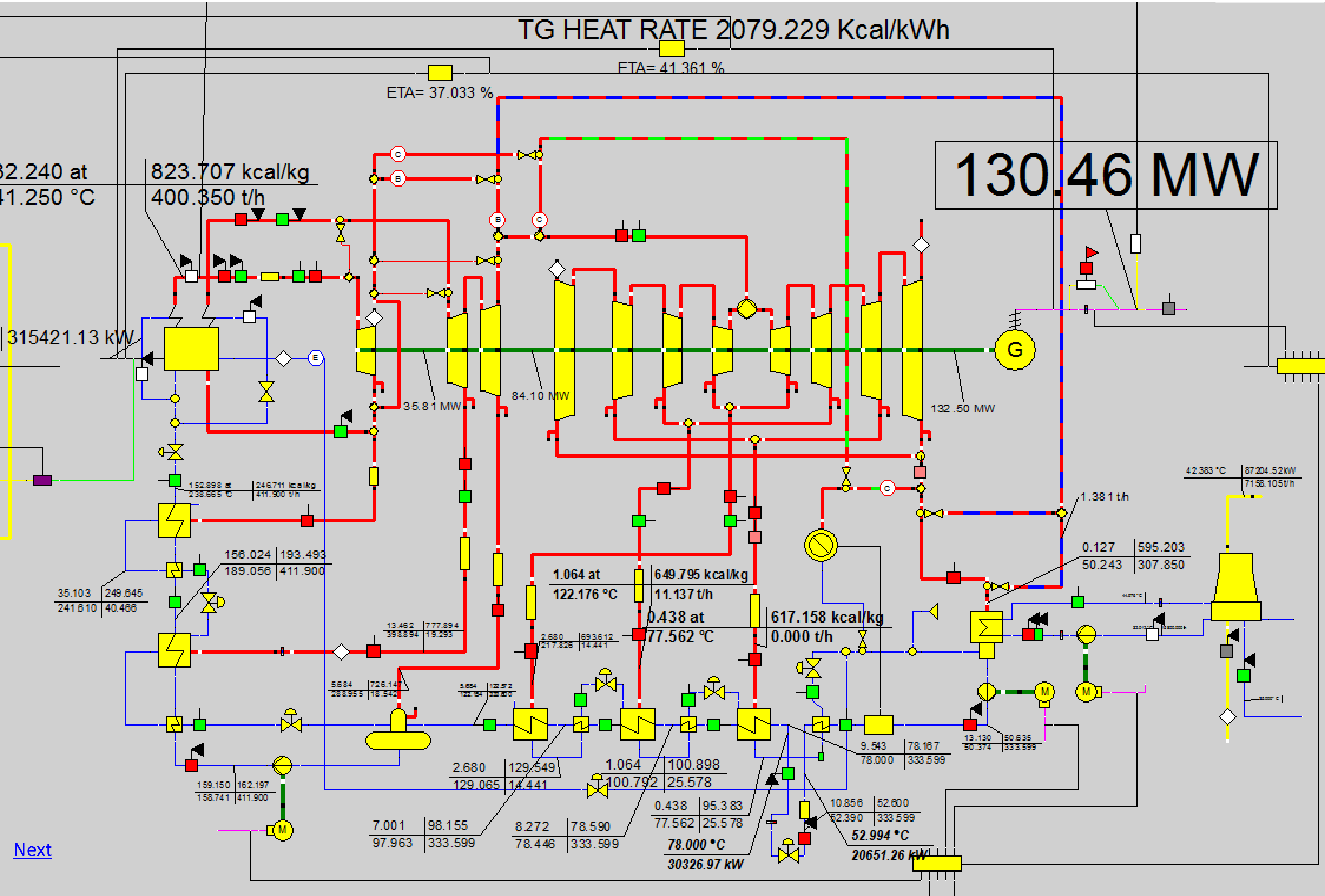

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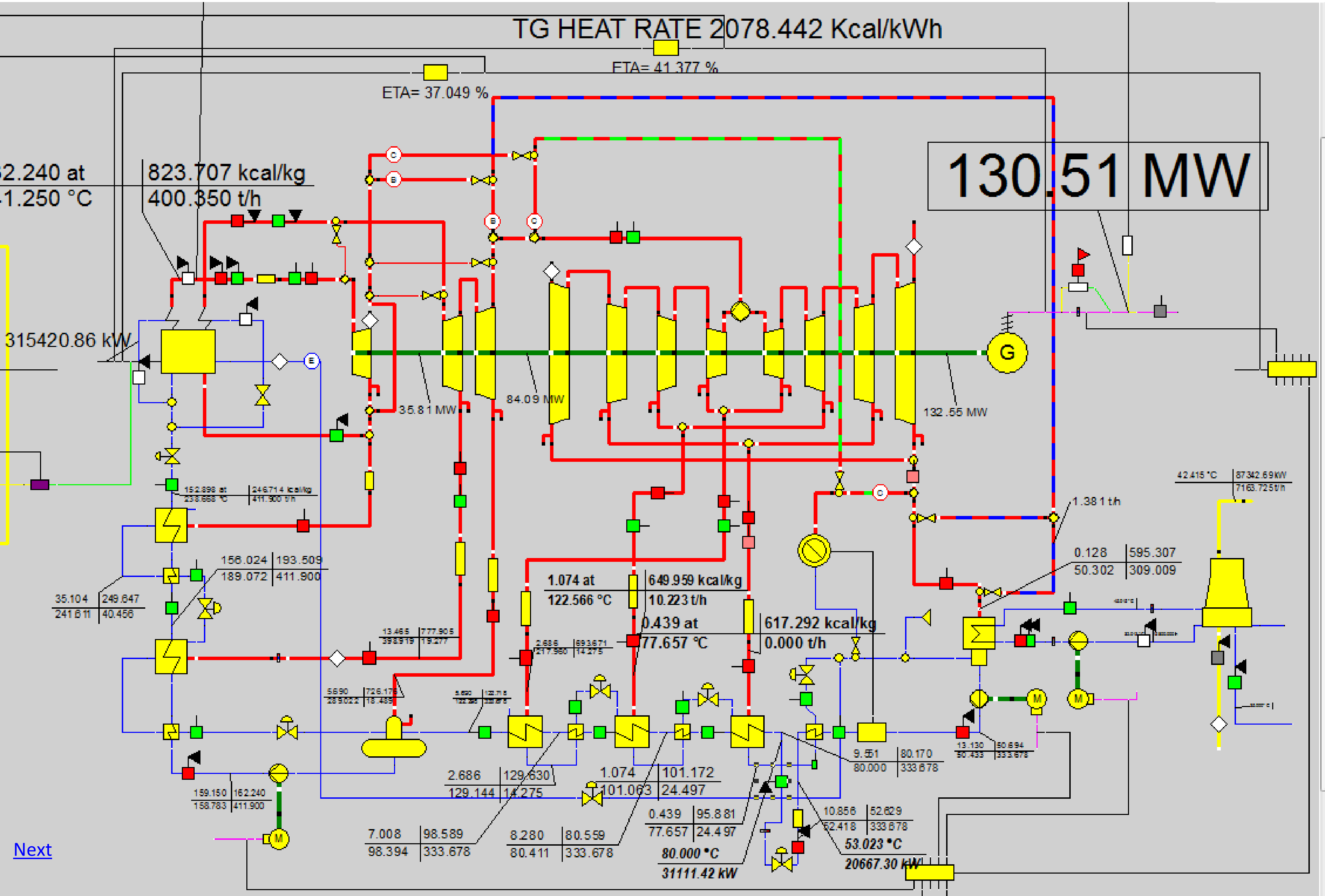

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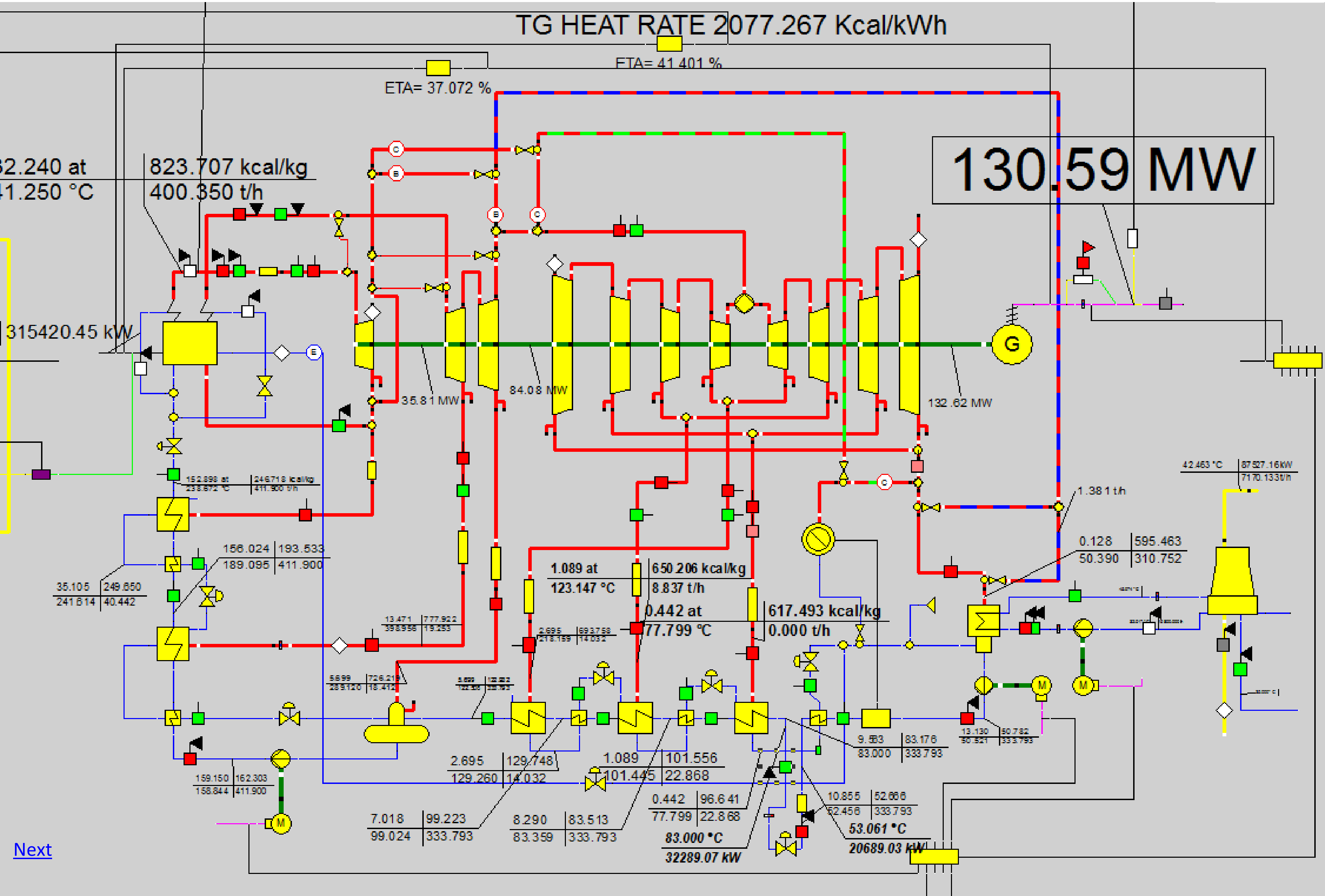

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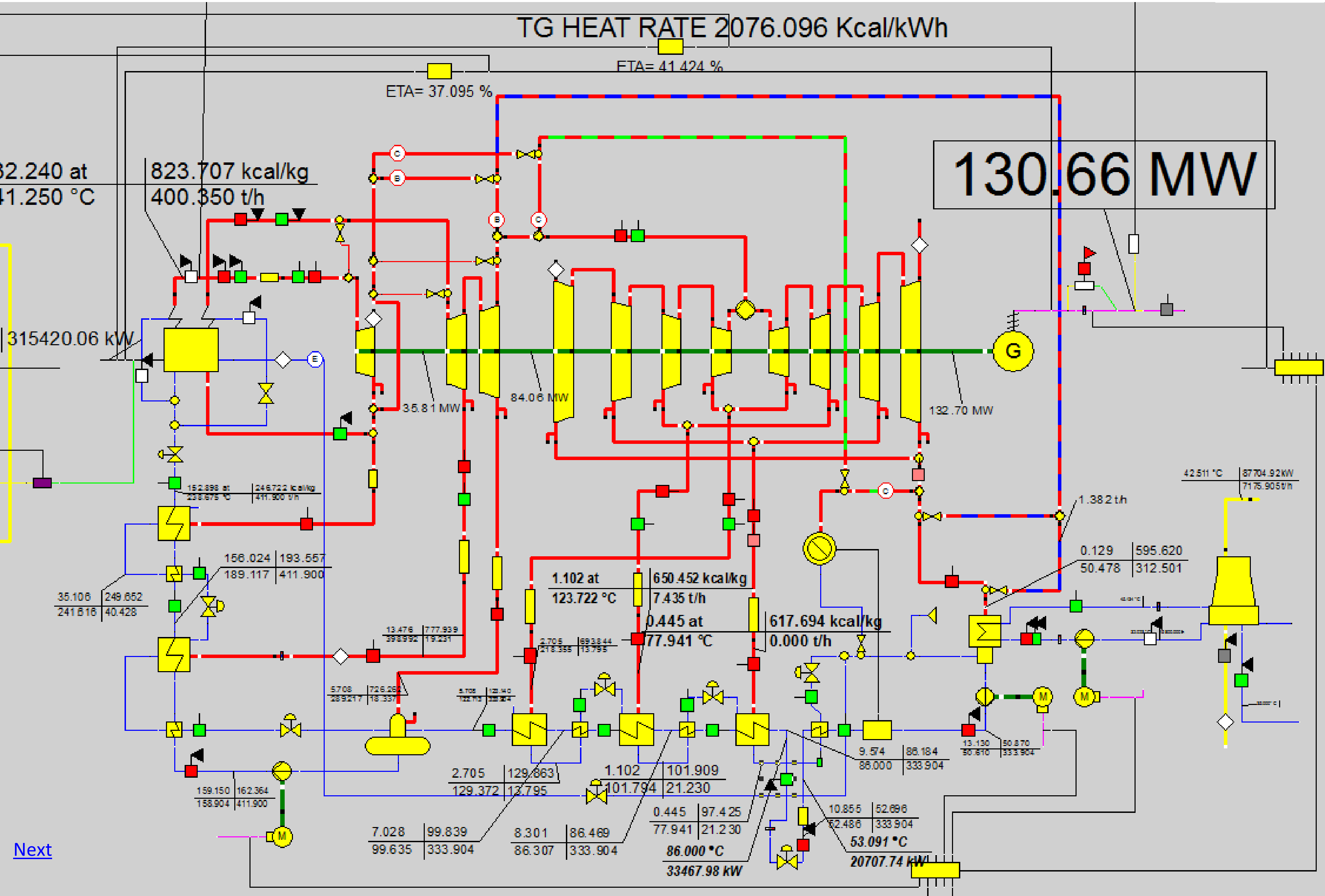

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Observations from the study of Ebsilon model :

1. Load increased by 0.34MW at same MS Flow, even though vacuum has been deteriorated by 4.0 mbar.
2. If we could maintain the vacuum by switching off one CCW pump (this will stop the bypass flow by 1000TPH & vacuum will improve) when Condensate temp has reached its max (86deg), then additional gain of 0.34MW may be achieved.
3. There is improvement in TG Heat-rate by 5.7 Kcal/Kwh when AC outlet temp OR LPH-1 inlet temp is max. at 86 deg. This will be at the most when bed ash is unloaded in one ash cooler up to 20 mbar comb dp.
4. Load may be made constant by reducing MS flow by 1.93 TPH at peak temp of condensate through ash cooler.
5. As condensate temp starts increasing, load shared by LPT starts increasing, while it starts reducing in IPT. HPT output remains constant throughout. But there is an overall gain in generated MW.
6. There will be a loss of 3.5KW in generated MW, if we consider one degree loss of temp. of condensate, for idle hours when no ash is being unloaded.
7. Extraction steam flow to LPH-1 becomes zero at @ 76 Deg C & above temps of condensate; extraction steam flow to LPH-2 never becomes zero while LPH-3 extraction steam flow remains unaffected.
8. Final temp gain in condensate water after LPH-3 remains unchanged.
9. In any case of temp rise in ash cooler, the pressure of water will always be well above saturation pressure, so there is no chance of steaming inside the coils.

Next

Utilization of Bed Ash Heat Drained out of Combustor in LPH Circuit
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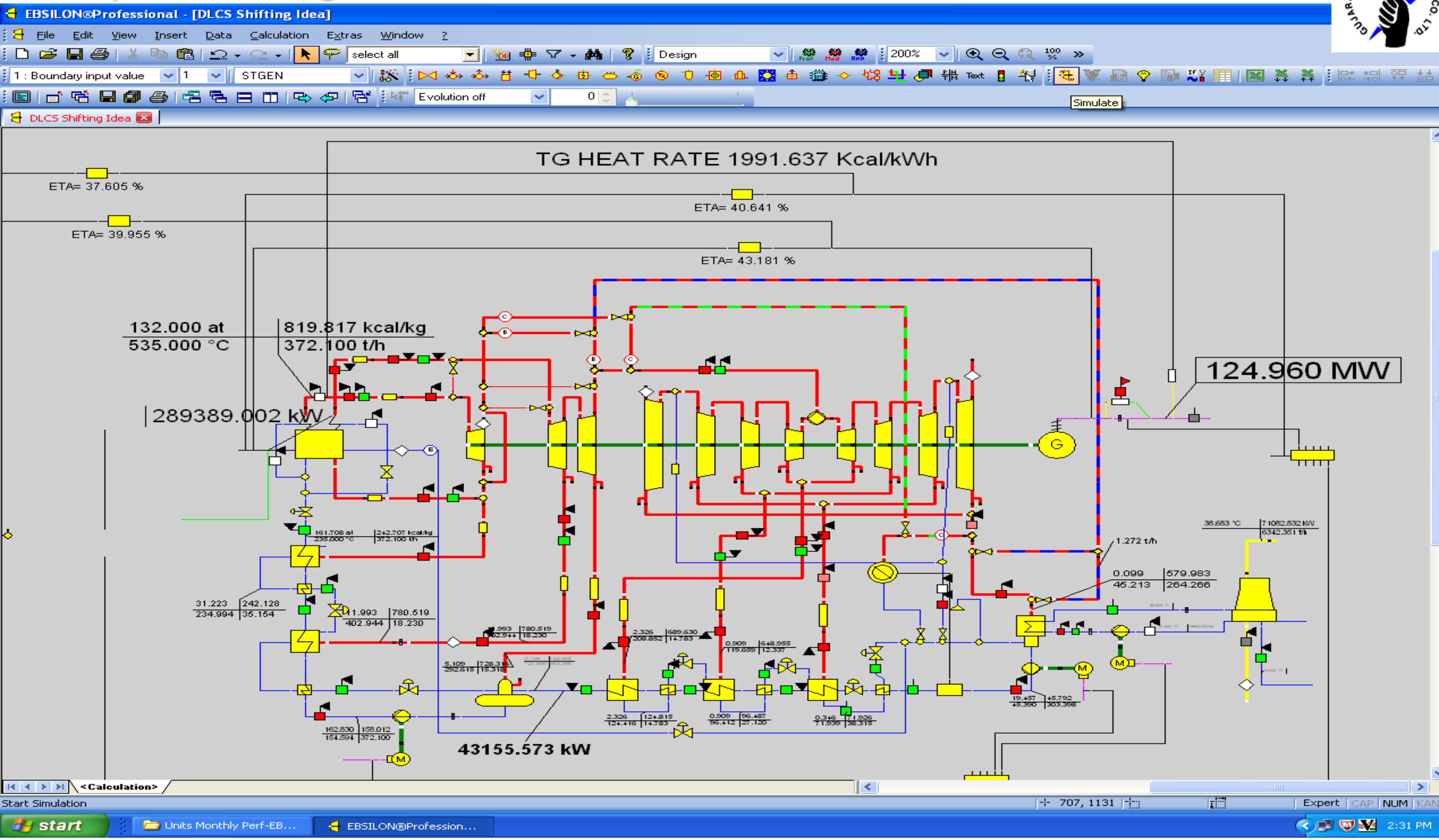
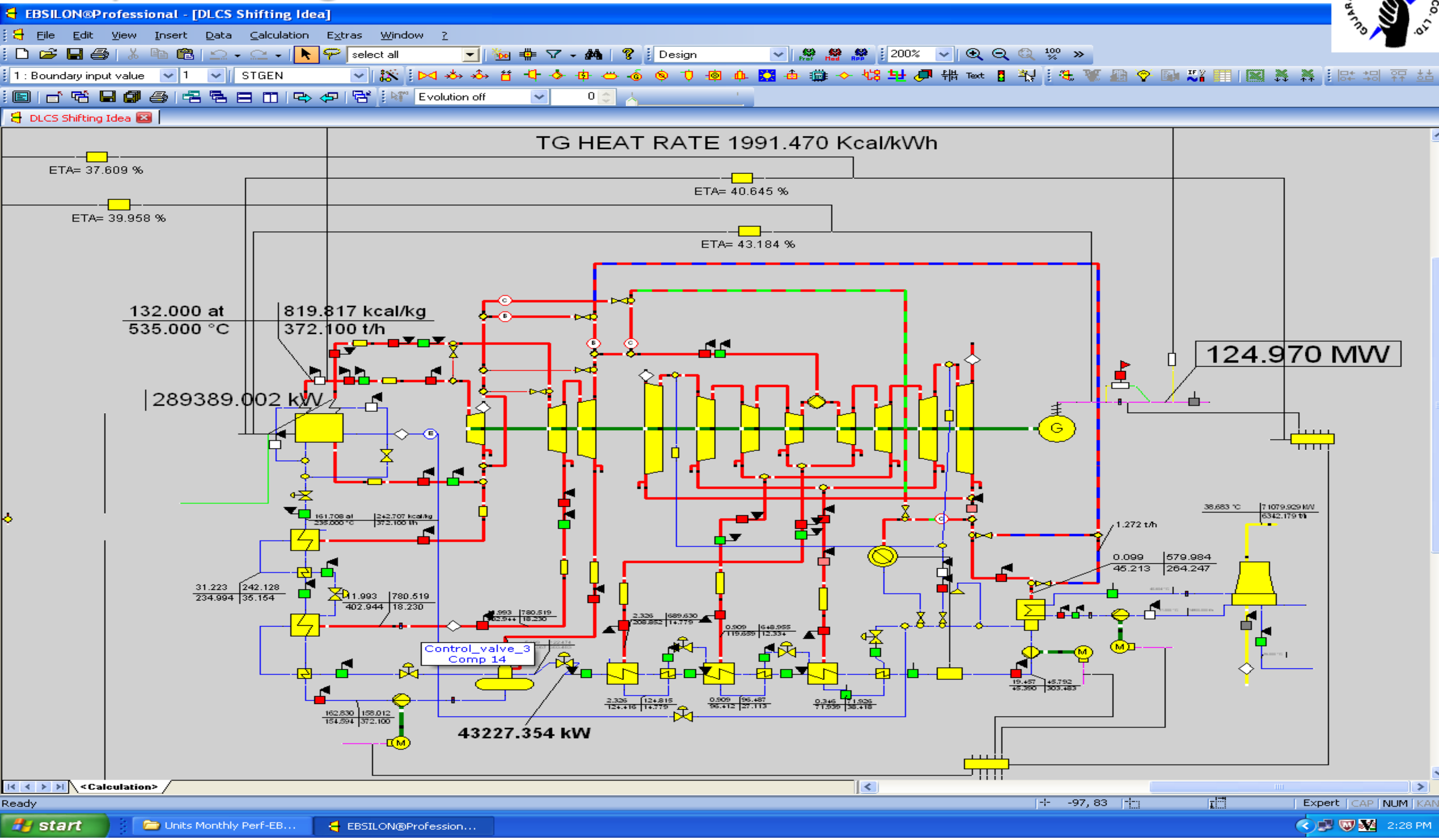
Particulars	Parameters in Full Load Case						Low Load Case	
	Before	After					Before	After
Load	125	125.01	125.05	125.06	125.12	125.34	93.06	93.35
Turbine Heat Rate	2090.737	2090.533	2089.91	2089.786	2088.699	2085.04	2090.104	2083.6
Main Steam Flow	385.43	385.43	385.43	385.43	385.43	385.43	285.43	285.43
Condenser Back Pressure-mbar	116.7545	117.3954	119.3091	119.6615	120.9889	122.6621	96	100.12
Steam Quality at LPT Exhaust	0.9533	0.9536	0.9544	0.9545	0.9551	0.9557	0.941538	0.944309
Steam Quality at LPH-1 Inlet	0.9723	0.9726	0.9736	0.9738	0.9744	0.9752	0.95946	0.962592
CW Inlet temp	34.3	34.3	34.3	34.3	34.3	34.3	34.3	34.3
CW Flow Taken at (TPH)	15800	15800	15800	15800	15800	15800	15800	15800
LPH-1 Condensate Inlet Temp	**51.262**	**55**	**66**	**68**	**76**	**86** Extreme case	**47.34**	**86** Not possible at low load
LPH-1 Condensate Outlet Temp	69.3	69.872	72.607	73.123	76.542	86.02	63.705	86.011
Extraction Stm Flow to LPH-1	9.557	7.92	3.073	2.199	0	0	6.62	0
LPH-1 Drip to DC Temp	74.635	75.058	76.024	76.157	76.542	76.988	67.676	69.959
LPH-1 Drip to DC Pressure	0.388	0.395	0.411	0.413	0.42	0.427	0.288	0.318
Saturation Temp at Drip Line	74.660	75.087	76.040	76.157	76.562	76.962	67.715	69.989
Difference	**-0.025**	**-0.029**	**-0.016**	**0.000**	**-0.020**	**0.026**	**-0.039**	**-0.030**
LPH-2 Condensate Inlet Temp	69.3	69.872	72.607	73.123	76.542	86.02	63.705	86.011
LPH-2 Condensate Outlet Temp	94.327	94.572	95.279	95.409	96.202	98.167	96.79	91.027
Extraction Stm Flow to LPH-2	14.121	13.74	12.608	12.393	10.917	6.66	9.719	1.949
LPH-2 Drip to LPH-1 Temp	98.22	98.399	98.912	99.005	99.537	100.699	89.535	92.18
LPH-2 Drip to LPH-1 Pressure	0.97	0.976	0.995	0.998	1.017	1.06	0.703	0.777
Saturation Temp at Drip Line	98.21	98.39	98.92	99.01	99.53	100.69	89.53	92.18
Difference	**0.005**	**0.013**	**-0.009**	**0.000**	**0.006**	**0.006**	**0.004**	**0.000**
LPH-3 Condensate Inlet Temp	94.327	94.572	95.279	95.409	96.202	98.167	96.79	91.027
LPH-3 Condensate Outlet Temp	120.366	120.837	120.685	120.729	120.988	121.621	111.727	112.843
Extraction Stm Flow to LPH-3	14.56	14.473	14.22	14.173	13.885	13.164	10.12	9.06
LPH-3 Drip to LPH-2 Temp	127.286	127.333	127.471	127.496	127.643	127.995	116.602	117.314
LPH-3 Drip to LPH-2 Pressure	2.539	2.543	2.554	2.556	2.567	2.595	1.817	1.859
Saturation Temp at Drip Line	127.280405	127.3322	127.4745	127.5003	127.6419	128.0002	116.5987	117.3076
Difference	**0.006**	**0.001**	**-0.003**	**-0.004**	**0.001**	**-0.005**	**0.003**	**0.006**
De-Aerator Pressure	5.428	5.431	5.441	5.443	5.454	5.48	3.921	3.956
Flow	17.819	17.79	17.708	17.692	17.601	17.377	11.717	11.418
Power Generated by								
HPT / IPT / LPT	33.78 / 47.45 / 45.93	33.78 / 47.44 / 45.95	33.78 / 47.42 / 46.01	33.78 / 47.42 / 46.02	33.78 / 47.4 / 46.11	33.78 / 47.36 / 46.37	24.8 / 40.13 / 31.43	24.8 / 40.06 / 31.79
Total Shaft Power at Generator Terminal	127.16	127.17	127.21	127.22	[illegible]	127.51	96.36	96.65

Study of Shifting of Dearator Level Control Station



De-aerator level control station controls the pressure of condensate required only to overcome the pipe resistance from DLCS to De-aerator via LPH-1,2&3 & de-aerator shell pressure plus height difference between DLCS & De-aerator. The required pressure ahead of DLCS is @9.0Kg/Cm2 whereas behind DLCS it is @ 19.5 Kg.CM2. If we can shift position of DLCS in LPH circuit after LPH-3, high pressure behind DLCS (i.e. CEP discharge pressure) will work more efficiently for heat transaction in LPHs.

Study of Shifting of De-Aerator Level Control Station



It is evident from the snapshots that before shifting the DLCS, total heat in condensate after LPH-3 was 43155.57KW$_{th}$, whereas after shifting the DLCS, total heat in condensate has been increased to 43227.35KW$_{th}$. It means that there is net increase of 71.78 KW in heat gain due to LPH-1, 2,& 3. An improvement of 0.167 Kcal/Kwh in Turbine heat rate is can also be witnessed. Assessment of feasibility & other aspects is expected from the experts.

Final Achievements FY 2013-14

Sr. No.	Description	Saving in Lacs KWHr	Saving in TOE
1	Performance Analysis of SAPH & PAPH Bottom Blocks Tubes Replacement work done in Unit-1 AOH 2013.	44.78	1136.52
2	Performance Analysis of SAPH & PAPH Bottom Blocks Tubes Replacement work done in Unit-3 AOH 2013	24.55	646.16
3	Performance Analysis of SAPH & PAPH Bottom Blocks Tubes Replacement work done in Unit- 4 AOH -2013.	32.60	858.03
4	Performance Analysis of SAPH & PAPH Bottom Blocks Tubes Replacement work done in Unit-2 AOH-2012.	23.82	604.55
5	Performance Analysis of SAPH & PAPH Bottom Blocks Tubes Leakage attending work done in Unit-2 AOH 2013.	28.16	714.70
6	Effect of Cooling Tower Fills Replacement work in Unit-2 on Condenser inlet water temperature & saving achieved thereof.	39.20	994.90
7	Unit-1 & 2 Condensate Extraction pumps de-staging decision taking & Power saving analysis	12.204	309.74
8	Power saving analysis in Air Compressor due to pressure reduction	2.290	58.12
9	Unit-3 Condenser vacuum improvement after tube cleaning, air ingress attending and CT fills cleaning, MAL valve passing attending work	39.6	996.5
10	Unit-3 Reduction in Reheater spray level	---	650.4
11	Unit-3 Reduction in Excess air	---	477
12	Unit-3 improvement of HP Heaters DCA	---	6.0
	TOTAL ACHIEVEMENT	**247.204**	**7452.62**

Under Consideration…

Sr. No.	Description	Saving potential in Lacs KWHr	Saving potential in TOE
1	Unit-3 & 4 Condensate Extraction pumps de-staging decision taking & Power saving analysis.	4.752	125.07
2	Power saving analysis in Air Compressor due to Air suction temperature reduction (3 running compressors considered).	1.314	33.35
3	Idea of Shifting of De-aerator Level Control Station from existing position (Before LPH-1) to new position (after LPH-3) & its effect on heat absorption (implementable in all four units).	3.88	100.3
4	Idea of waste heat recovery from bed ash drained from the combustor using condensate water & feeding it to LPH-1. (implementable in phase-II units).	---	1490
	TOTAL	9.946	1748.7

THANK YOU FOR YOUR ATTENTION