

## Energy Audit for Power Plants



## **1. Introduction**

Why do it? Just like a motorist who finds his car petrol consumption increasing but cannot pinpoint if the problem is due to his driving habits, tyre pressure, fuel quality, uneven fuel injection, sticky brakes, faulty spark plugs, dirty valves etc. This is the same challenge facing the power plant operator who sees the thermal efficiency dropping but does not know which are the contributing plant component(s). An energy audit will comprehensively identify the degraded plant components and their respective contribution to overall thermal efficiency loss and therefore will be valuable input into the next inspection maintenance scope to implement the necessary corrective actions. Having established the baseline performance the energy audit can easily be extended to studying the feasibility of potential retrofit improvements to the plant.

## **2. Energy Audit Methodology**

Actsyst adopts thermodynamic simulation based analysis for the performance assessment of individual major elements in the plant and also to assess the overall plant efficiency. The performance assessment can typically be applied to:

- Comparing actual performance to “Guarantee Performance” or to any other reference performance
- Comparing different conditions or modes of operation
- Assessing the impact of individual equipment performance’s variation on overall plant efficiency
- Assessing the impact of different retrofit options

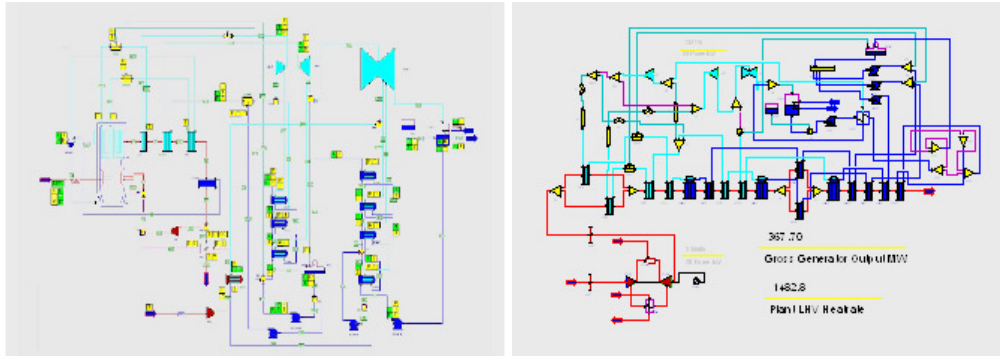
Efficiency / baseload gain potential by restoring the deteriorated performance of individual equipment and by upgrading / retrofitting the plant equipment can also be established by performing various simulation based analysis.

In this document, the various steps involved in the energy study are explained with typical case study illustrations. The overall energy study analysis involves following steps:

- Heat Balance Analysis
- New & Clean (N&C) Analysis
- Performance Gap Impact Analysis
- Retrofit Analysis

## A. Heat Balance Analysis

This set of calculation will be carried out using a heat balance model setup using the GE Energy's thermodynamic modeling software Gatecycle.



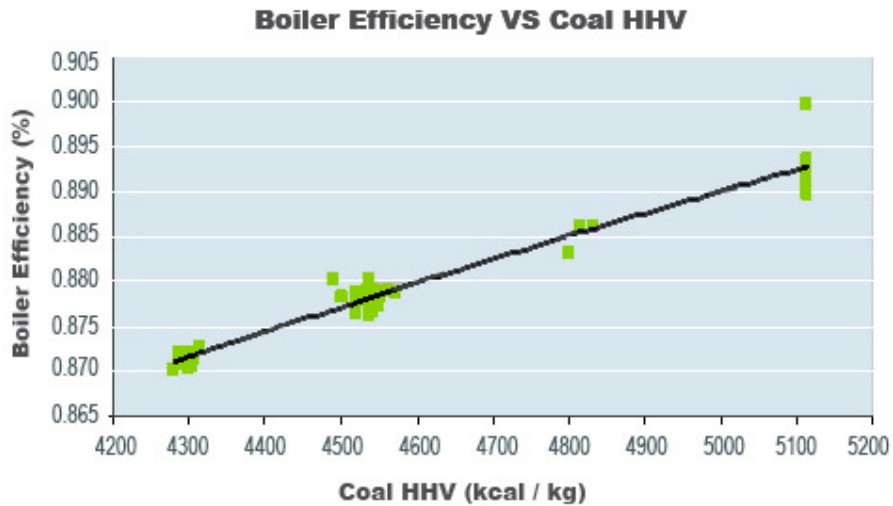
Performing heat and mass balance calculation of the whole plant helps in establishing the various unknown parameters in terms of flow, pressure and temperature of different streams such as feedwater, steam, air, flue gas and cooling water. As the heat balance analysis calculates every individual stream parameter, it enables us to counter check the measured parameter value for ensuring the accuracy of the same.

Eventually it helps in ensuring the usage of more reliable and accurate measurement which results in better accuracy of the analysis results. Examples of key parameters that can be established through the heat balance calculation are shown in the following table.

Thermal Power Plant	Combine Cycle Plant
<ul style="list-style-type: none"> <li>▪ Combustion Heat Release</li> <li>▪ Boiler Efficiency</li> <li>▪ Steam Turbine Extraction Flow and Drain Flow</li> <li>▪ Economiser Effectiveness</li> <li>▪ Steam Turbine HP, IP and LP Section Power and Efficiency</li> <li>▪ Feedwater Heaters Terminal Temperature Difference and Drain Cooler Approach</li> <li>▪ Cooling Water Flow to Condenser</li> <li>▪ Condenser Effectiveness</li> <li>▪ Air Heater Leakage</li> <li>▪ BFW Pump Efficiency</li> </ul>	<ul style="list-style-type: none"> <li>▪ Fuel Consumption</li> <li>▪ GT Compressor Air Flow and Exhaust Flow</li> <li>▪ GT Compressor Efficiency and GT Turbine Efficiency</li> <li>▪ Steam Turbine HP, IP and LP Section Power and Efficiency</li> <li>▪ HP Bypass Valve Condition – to detect the presence of any valve passing</li> <li>▪ Cooling Water Flow to Condenser</li> <li>▪ Feedwater Preheater Performance</li> <li>▪ Feedwater Preheater Bypass Valve Condition – to detect the presence of any valve</li> </ul>

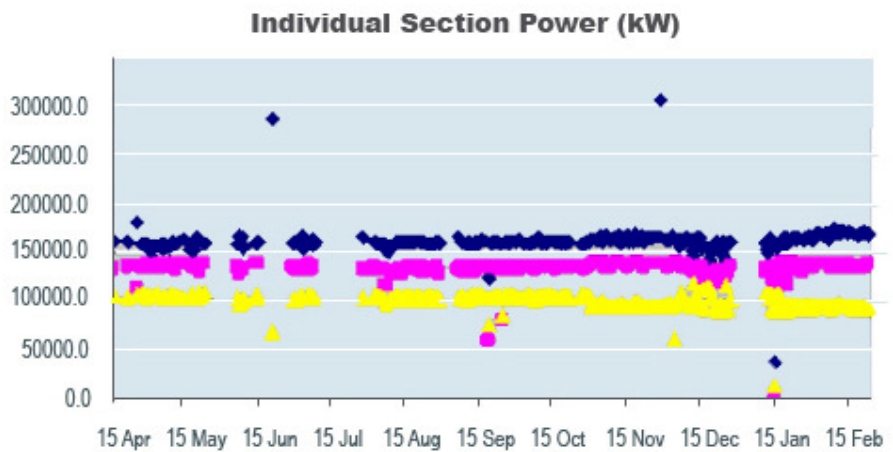
**A. Heat Balance Analysis (Cont'd)**

**Typical Illustration of N&C Analysis Results**



■ Boiler Efficiency    — Log (Boiler Efficiency)

In this case, the calculated Boiler Efficiencies correlates with calculated coal HHV in the expected manner, thereby giving confidence to the load cell coal flow readings at mill inlet

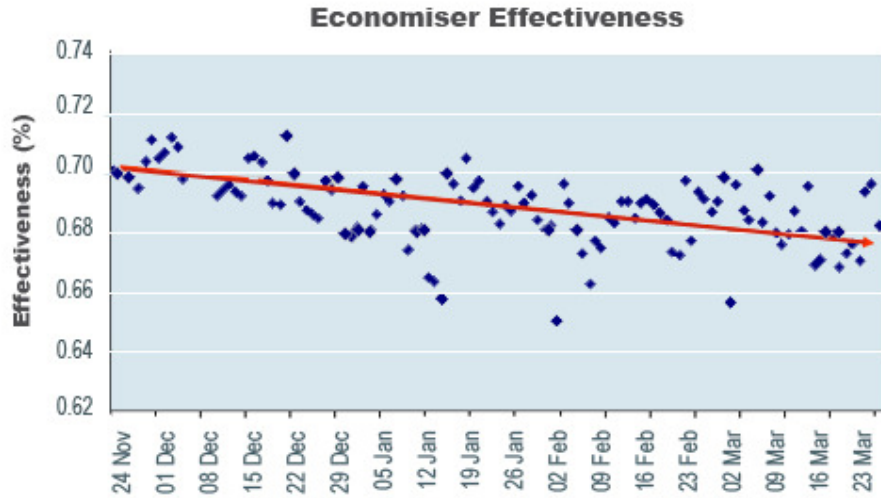


◆ LPST Power    ■ IPST Power    ▲ HPST Power

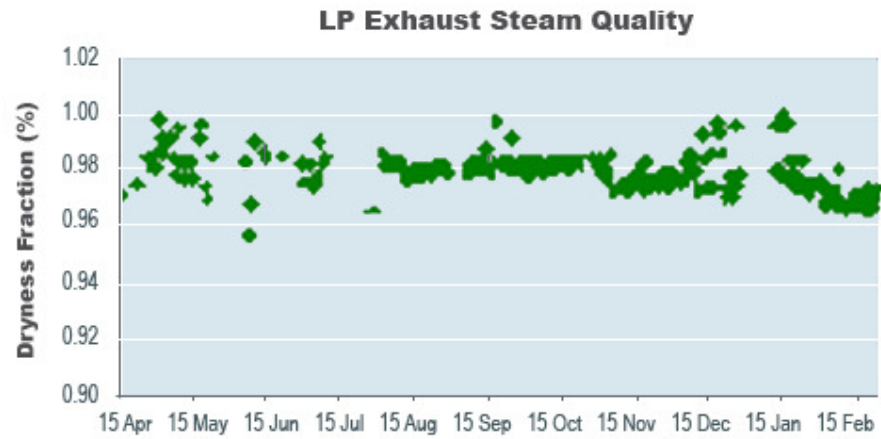
Individual section power of steam turbine sections is quantified and trended

**A. Heat Balance Analysis (Cont'd)**

**Typical Illustration of N&C Analysis Results**



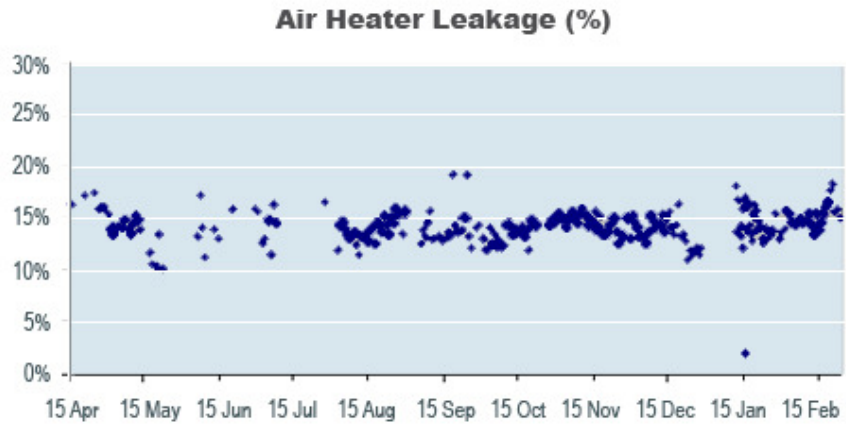
Individual component performance of boiler like economizer can be assessed



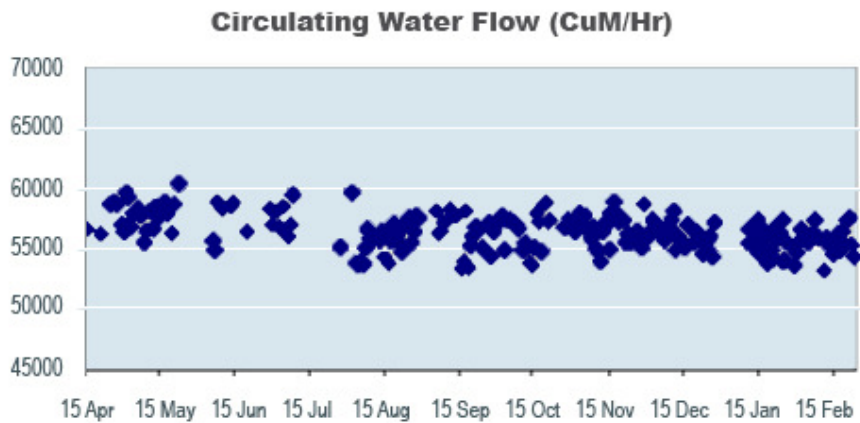
LPST exit quality which is not measured at site can also be quantified and monitored

**A. Heat Balance Analysis (Cont'd)**

**Typical Illustration of N&C Analysis Results**



Air heater leakage is quantified and can be confirmed by various other calculations.

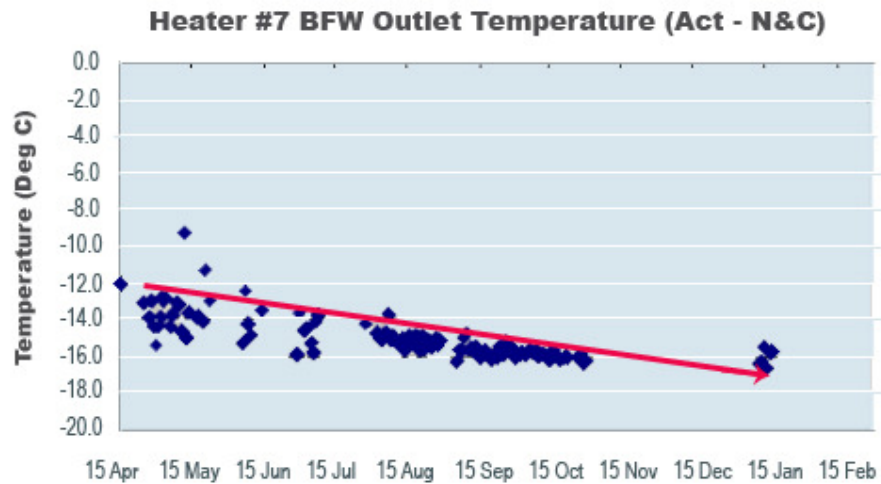


CWP water flow, which is key to assess the condenser & CWP performance can be established.

### **B. New & Clean (N&C) Analysis**

New and Clean performance calculations are performed to quantify the performance targets for the various individual equipments. Individual GE Gatecycle models will be configured to assess the performance targets of various equipments like GT, Steam Turbine, Condenser, HRSG, Economiser, Feedwater Heaters, Convection Zone Superheaters and Boiler Feedwater Pumps. Performance targets would be compared with the heat balance calculated current performance to ascertain the performance gap.

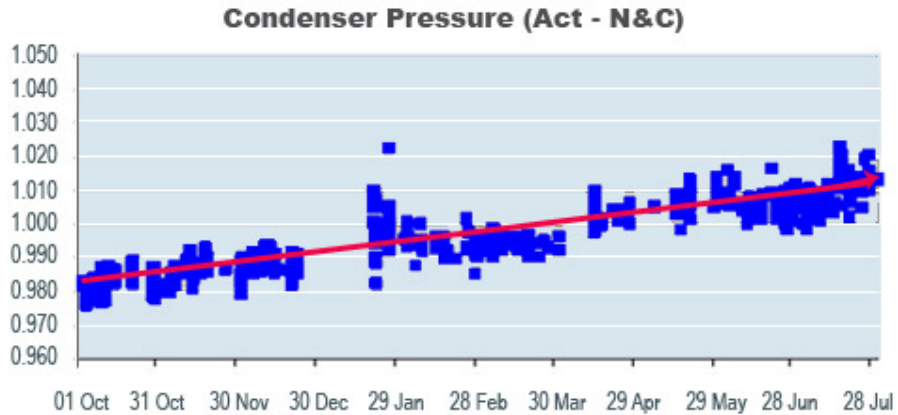
### **Typical Illustration of Heat Balance Results**



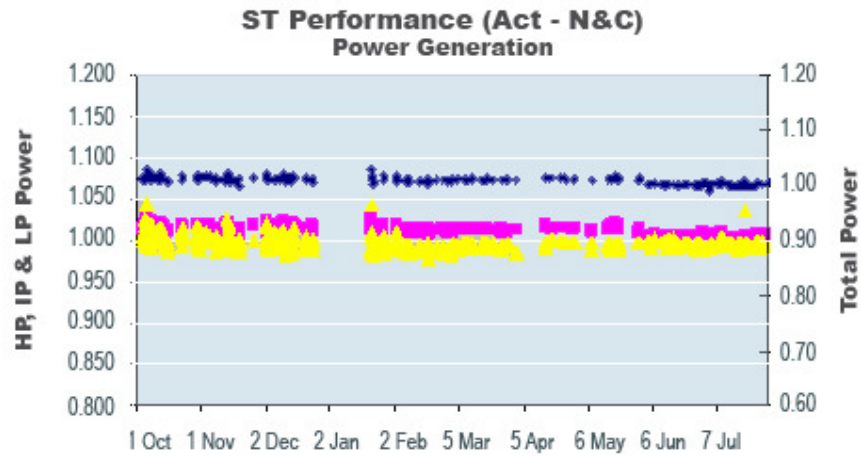
Deterioration in individual equipment performance can be monitored over a period of time. This enables to take timely action to restore the heater performance

**B. New & Clean (N&C) Analysis (Cont'd)**

**Typical Illustration of Heat Balance Results**



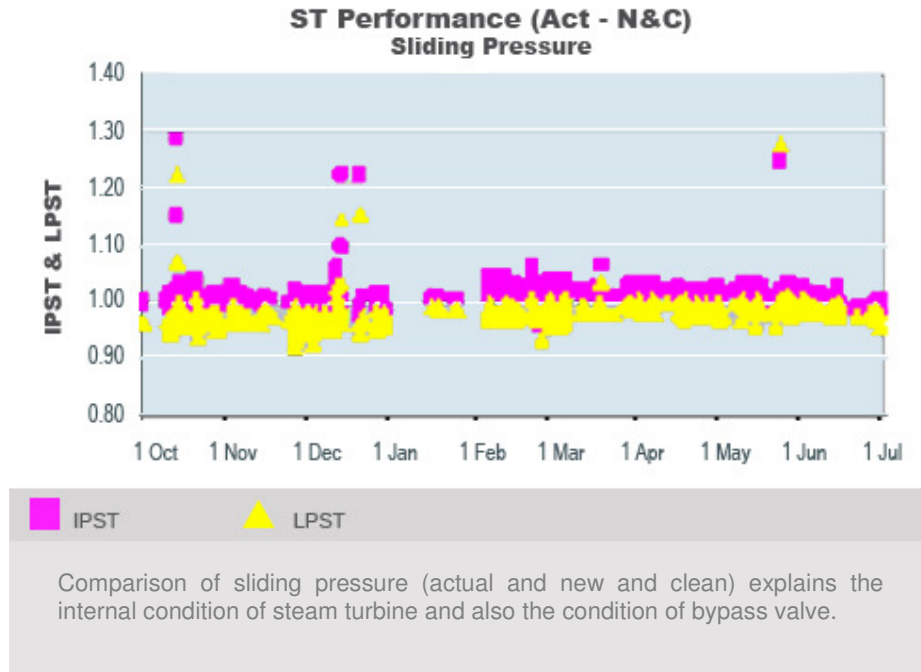
Condenser performance would deteriorate over a period of time. Analyzing the deviation of the actual condenser pressure from N&C condenser pressure could reveal various reasons. In the above case, the increase in condenser pressure (Act/N&C) is due to passing of IP bypass valve



Steam turbine performance is assessed by comparing the actual steam turbine section power with the new and clean steam turbine power and also by comparing the actual sliding pressure of the individual section with the new and clean sliding pressure.

**B. New & Clean (N&C) Analysis** (Cont'd)

**Typical Illustration of Heat Balance Results**



**C. Performance Gap Impact Analyses**

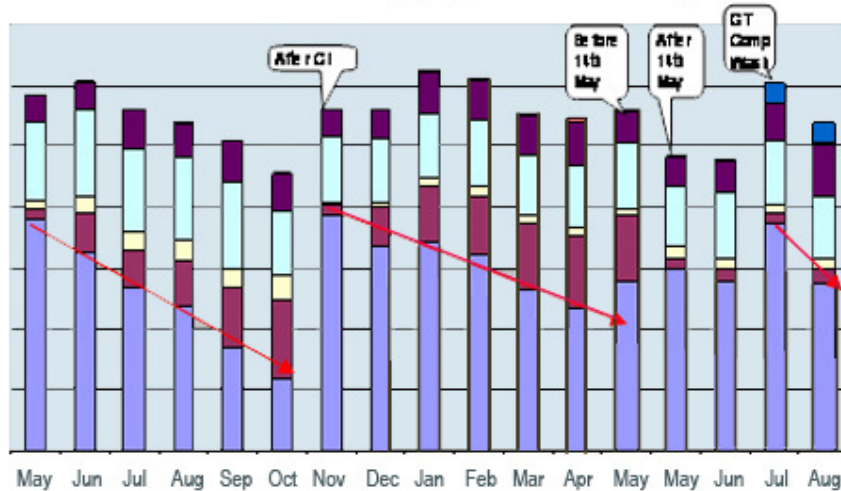
Heat balance analysis and N&C analysis illustrate the performance gap of individual equipment and overall plant. To translate the quantified performance gaps into more meaningful results that would be helpful in condition based predictive maintenance decision making to enhance overall efficiency, more simulation model analysis is performed to understand various “What-if” scenarios. These “What-if” simulation analyses quantify the impact of individual equipment degradation on overall plant efficiency. Thereby enabling optimal scheduling and prioritization of maintenance activities.

Some of the case illustrations that highlight the importance of performance gap impact analyses modeling are shown below.

**C. Performance Gap Impact Analyses (Cont'd)**

**Typical Illustration of Performance Gap Impact Analyses**

**Present Thermal Efficiency (%) & Potential Improvement**

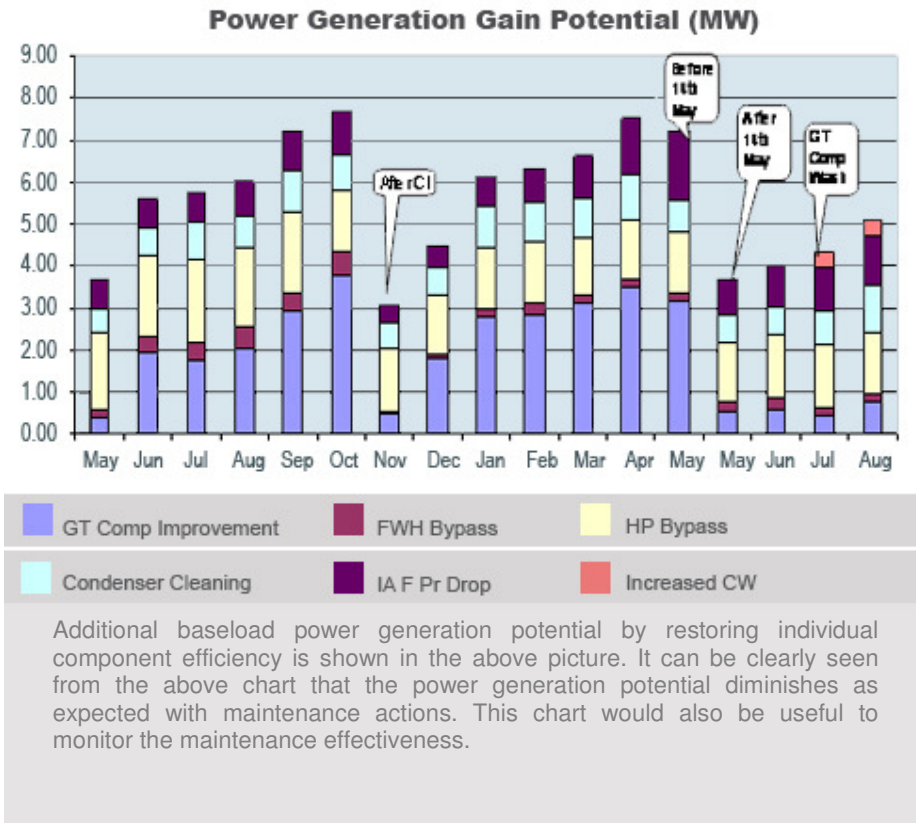


Present    
  FWH Bypass    
  Condenser Cleaning    
  Increased CW  
 GT Comp Improvement    
  HP Bypass    
  IAF Pr Drop

Above chart shows the deterioration in actual plant efficiency over a period of time and corresponding increase in individual component performance losses. Individual component performance loss is expressed in terms of potential thermal efficiency improvement through restoring the performance of the same.

**C. Performance Gap Impact Analyses (Cont'd)**

**Typical Illustration of Performance Gap Impact Analyses**

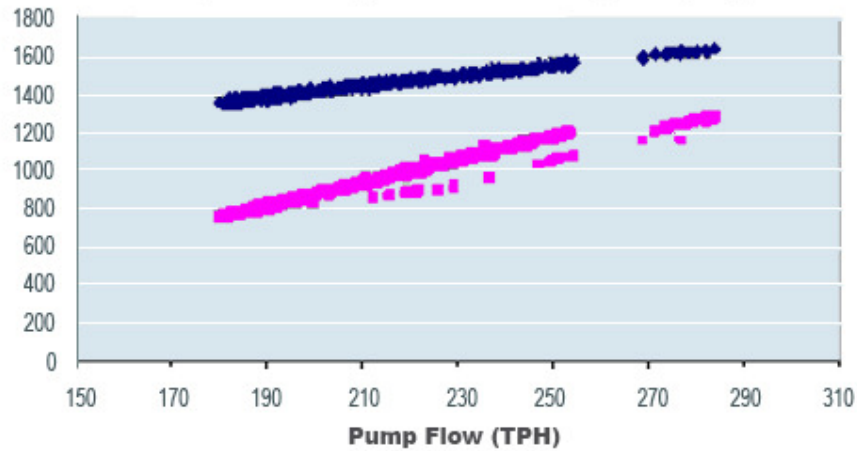


**D. Retrofit Analyses**

Understanding the individual component degradation through heat balance and new and clean model analysis is useful for building a “whole” plant simulation model i.e the entire plant performance can be predicted for various operating conditions/modes. This kind of simulation technique helps in ascertaining the benefits associated with various retrofit projects. Few case studies that illustrate the retrofit analysis are shown below:

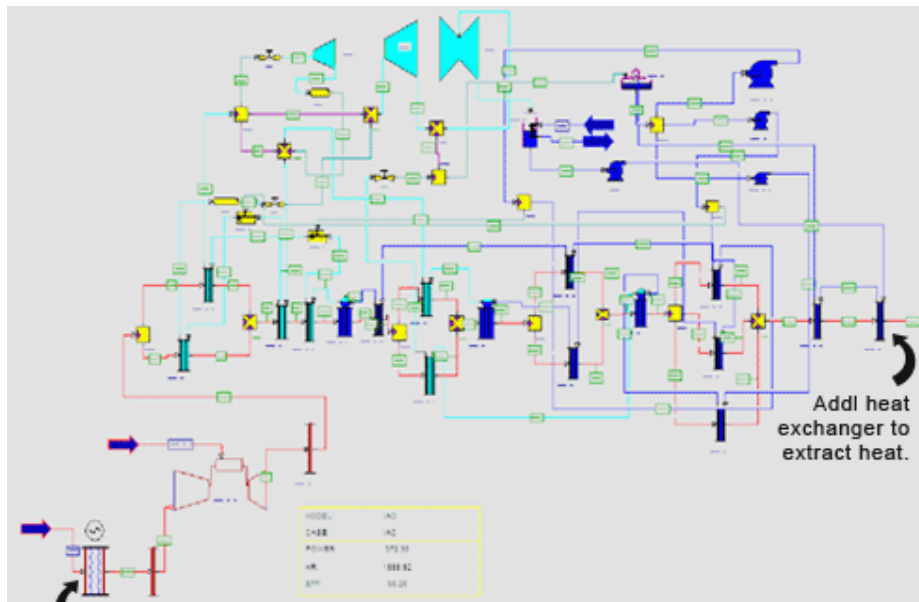
**D. Retrofit Analyses** (Cont'd)

**Actual Pump Power Consumption VS Proposed Pump Power Consumption (kW)**



◆ Present Power Consumption      ■ Power Consumption VSD

Benefits through implementation of variable speed drive for a boiler feed pump was quantified for one of the case. A simulation model is configured to simulate various operating conditions of boiler feed pump. Reduction in power consumption is quantified at various operating points



2 retrofit cases are studies here using whole plant simulation analysis. The first being benefits of installing inlet air cooler to a CCP GT is calculated. The second is the viability of additional heat extraction from the flue gas through incorporation of additional heat exchanger surface area in the existing HRSG system. Possibility of hot water generation and utilization for plant air conditioning (with vapour absorption system) is also worked out.

### 3. Project References

Client	Location	Type of Project	Period	Project Description
Prai Power (Malakoff) (Ongoing)	Malaysia	Performance Monitoring	2007	Performance monitoring of Combined Cycle Block (1 x 370MW)
Senoko Power (Ongoing)	Singapore	Efficiency Review	2007	Efficiency review of Combined Cycle Unit # 3 (1 x 360 MW) to check the performance before and after maintenance.
Power Seraya (Ongoing)	Singapore	Performance Monitoring	2007	Performance monitoring of 2 x 250MW Steam Plants
Power Seraya (Ongoing)	Singapore	Performance Monitoring	2007	Performance monitoring of Combine Cycle Blocks 10 & 20 (2 x 370 MW) for all 12 months in 2007.
Tuas Power (Ongoing)	Singapore	Performance Monitoring	2004 – present	Performance monitoring of Combined Cycle Blocks I & II (2 x 367 MW) – Project being done from 2004 onwards and the contract signed till the end of 2007.
Tuas Power (Ongoing)	Singapore	Performance Monitoring	2005 – present	Performance monitoring of Combined Cycle Blocks III & IV (2 x 367 MW) for all 12 months in 2007.
Central Utility Facility (CUF), Petronas Gas Berhad	Gebeng, Malaysia	Feasibility Study	2006	Feasibility Study to check the techno-commercial feasibility of an energy saving option to reroute the condensate line in this central utility facility.
Prai Power (Malakoff)	Malaysia	Training	2006	Training Module on Combine Cycle Plant Energy Balance Principles and Hydraulic Calculation Basics
Tanjung Bin Power (Malakoff)	Malaysia	Training	2006	Training Module on Coal Fired Plant Basic Principles and Thermodynamic Modeling Aspects
Power Seraya	Singapore	Energy Audit & Performance Monitoring	2005	Orimulsion fired Steam thermal power plant (1 x 250 MW) Energy Audit & Plant Efficiency Performance Monitoring Program
Paiton Power Plant, Jawa Timur, Pembangkitan Jawa Bali (PJB)	Indonesia	Performance Monitoring	2005	2x400 MW Coal Fired Steam Plant Efficiency Program
PT MTS (Maintenance Total Solutions)	Indonesia	Training	2005	Asset Optimization Program Seminar - Presentation on Plant Efficiency Performance Monitoring Program
Tuas Power	Singapore	Feasibility Study	2004	Feasibility Study of Thermal Energy Storage System.
Muara Karang Power Plant, Jakarta, Pembangkitan Jawa Bali (PJB)	Indonesia	Performance Monitoring	2004	Combined Cycle Plant Maintenance Optimization Program: Plant Efficiency, Performance Monitoring & Maintenance at 2x200 MW Steam Plant and 500 MW (3+3+1 Combined Cycle Plant)
Gulf Electric NongKhae	Thailand	Performance Monitoring	2004	Implementation of GE Enter Efficiency Map Online Performance Monitoring & Optimization System
Gresik Power Plant, Gresik Jawa Timur, Pembangkitan Jawa Bali (PJB)	Indonesia	Performance Monitoring	2004	2x200 MW Steam Plant and 480 MW 3+3+1 Combined Cycle Plant Efficiency Program
Gulf Electric Samutprakarn	Thailand	Performance Monitoring	2003	Implementation of GE Enter Efficiency Map Online Performance Monitoring & Optimization System
Nanyang Technological University,	Singapore	Training	2003	Mechanical Engineering Course Energy Conversion Module - Practical Application of Thermodynamic Simulation Software
Electricity Generation Authority of Thailand (EGAT)	Thailand	Training	2002	Providing training on power plant thermodynamic simulation tool Gatecycle™.