COMBINING ADVANCED DATA ANALYSIS METHODS FOR THE CONSTITUTION OF AN INTEGRATED GAS TURBINE CONDITION MONITORING AND DIAGNOSTIC SYSTEM

A.Tsalavoutas,
N. Aretakis,
A.Stamatis ,
K. Mathioudakis ,

Laboratory of Thermal Turbomachines
National Technical University of Athens

Combining Advanced Data Analysis Methods For The Constitution Of An Integrated Gas Turbine Condition Monitoring And Diagnostic System

- **Desirable features and basic functions of a System**
- **Features of individual system functions**
  - *Data acquisition and management*
  - *Thermodynamic analysis*
  - *EGT monitoring*
  - *Vibration monitoring*
- **Application test-case: Industrial gas turbine**
- **Summary – Conclusions**

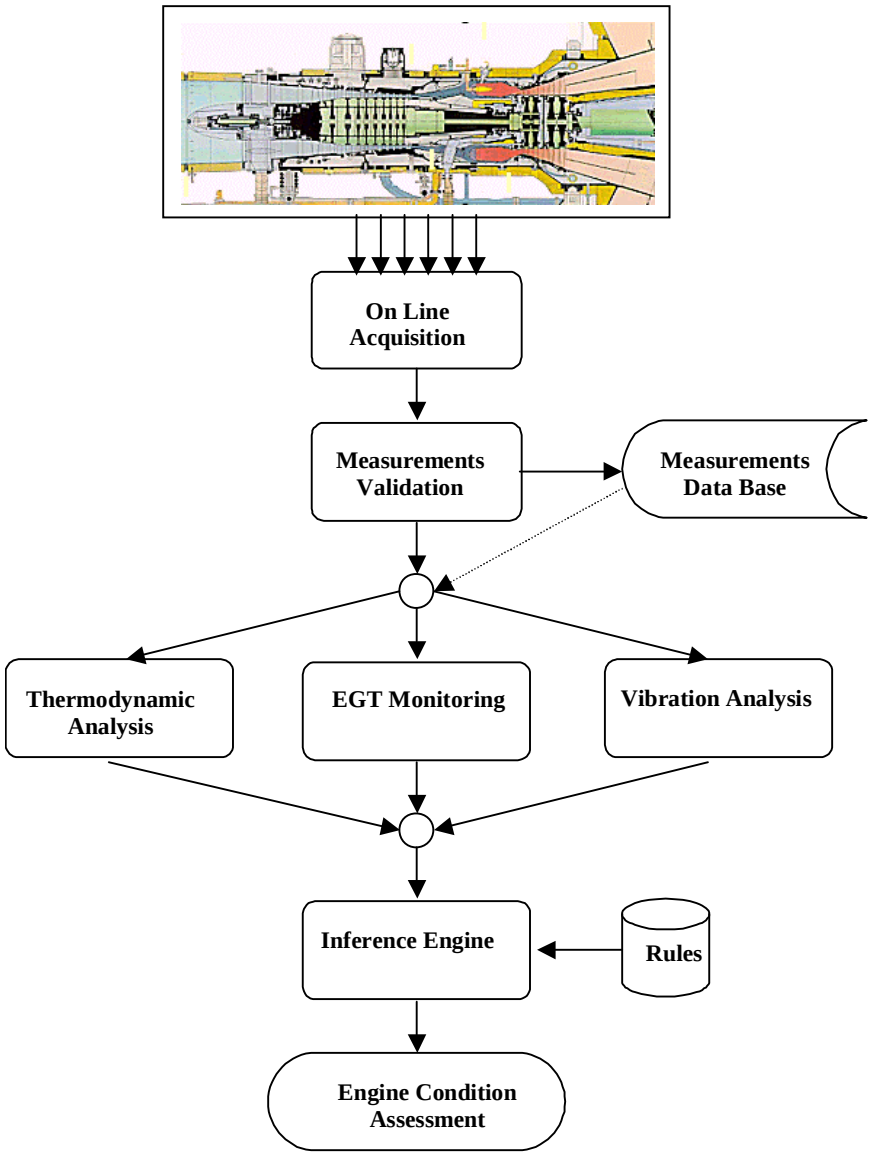
Desirable Features of Monitoring System

- **Automated, Integrated**
  - *Performing all actions from data collection to derivation of diagnostic decisions.*
- **Provide information with high confidence**
  - *Derivation of the same conclusion by different methods is a very useful feature.*
- **User friendly**
  - *Used by non-specialized personnel, output clear enough to need very little or no interpretation.*
- **Wide coverage of detectable faults**
  - *Allow additions of new faults, which have not been initially included*
- **Prognostic capabilities**
  - *Helps ensuring that spares are available and that outages be minimized*
- **"Robust"**
  - *Not susceptible to noise or faulty input information*
- **Employ as few instruments as possible**
- **Modular and flexible**
  - *Open architecture to be adapted to operator's needs*

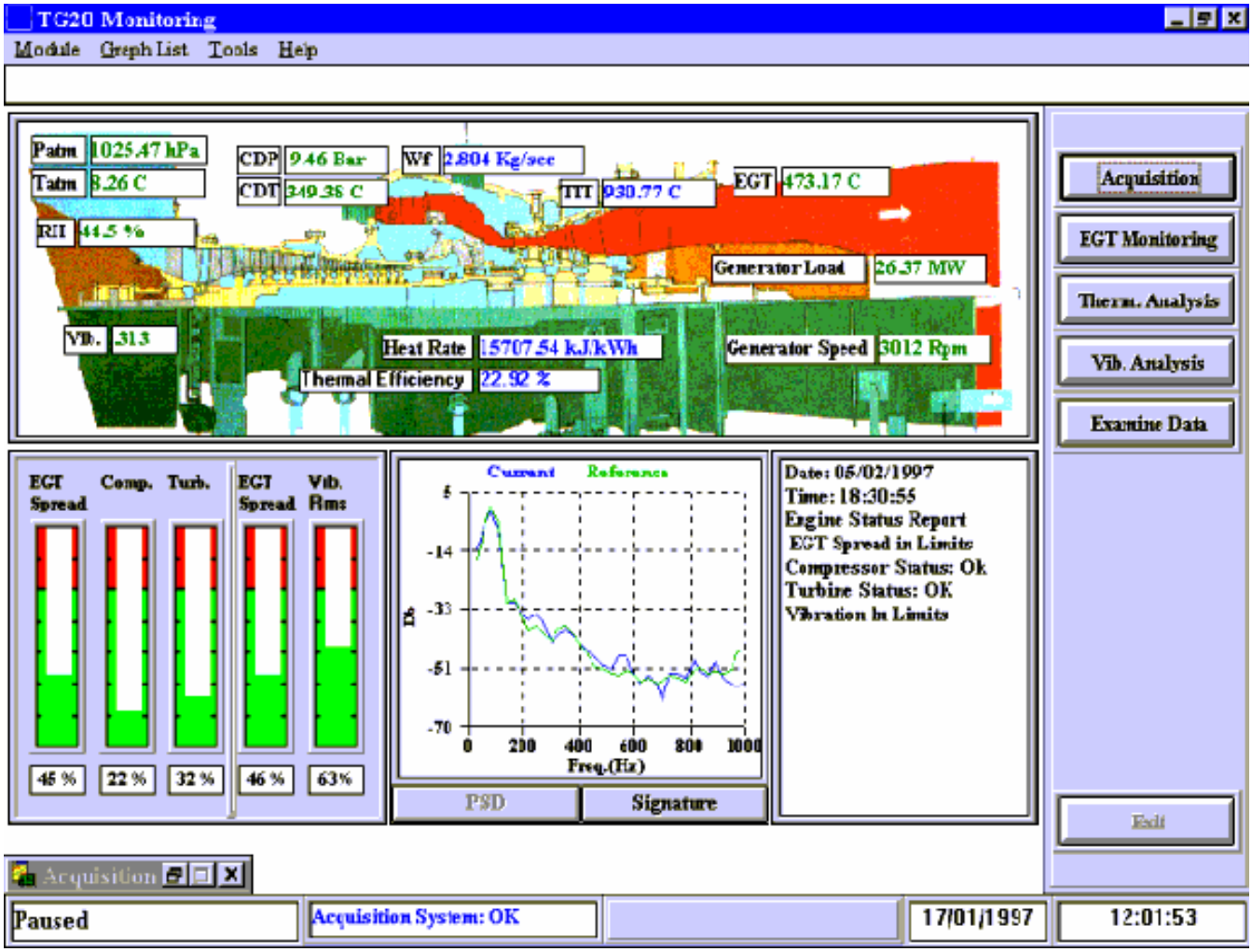
The Main Function to be Implemented in a Monitoring System

- **Measurement data acquisition.**
- **Data evaluation: discard unreliable readings and possibly detect sensor faults.**
- **Data processing: to derive diagnostic information**
- **Diagnostic inference: what is the nature, the location and the severity of a malfunction present**
- **Data management: keep historical data records for long term monitoring, without too much storage**

Functional Diagram Of The Gas Turbine Condition Monitoring System.



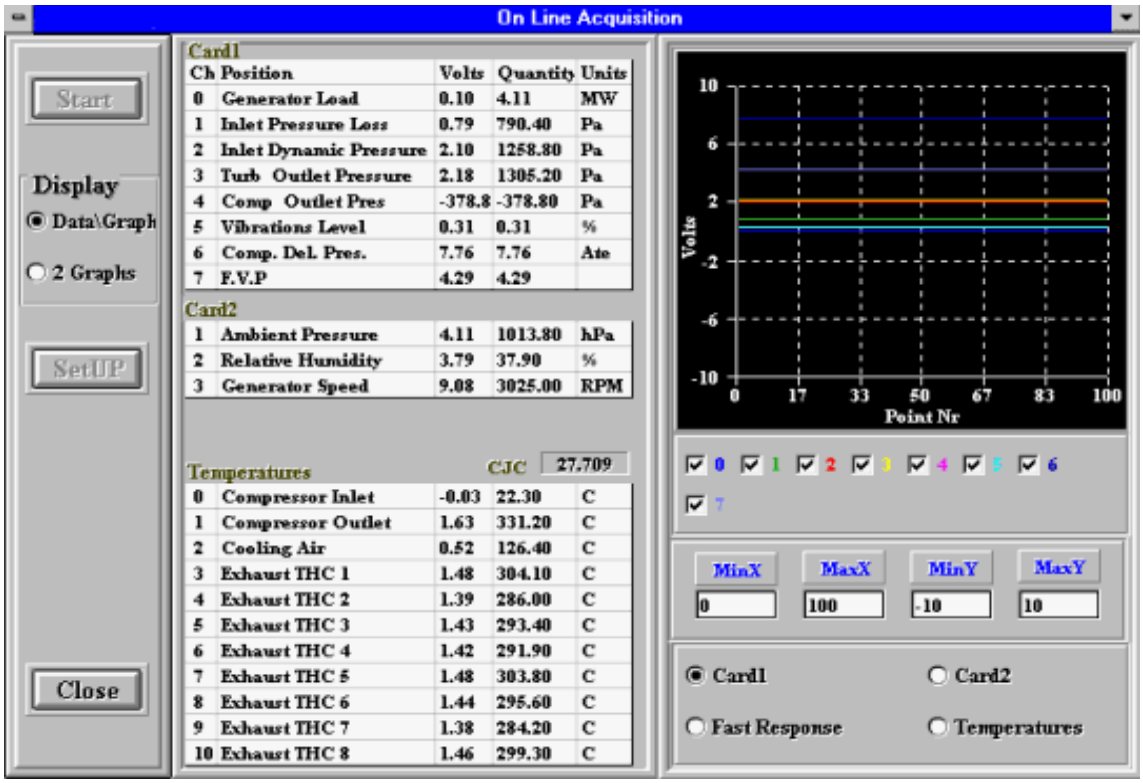
Main Interface Of The Condition Monitoring System.



Data Acquisition

Inspection of Measured Data

Example of on-line acquisition screen.

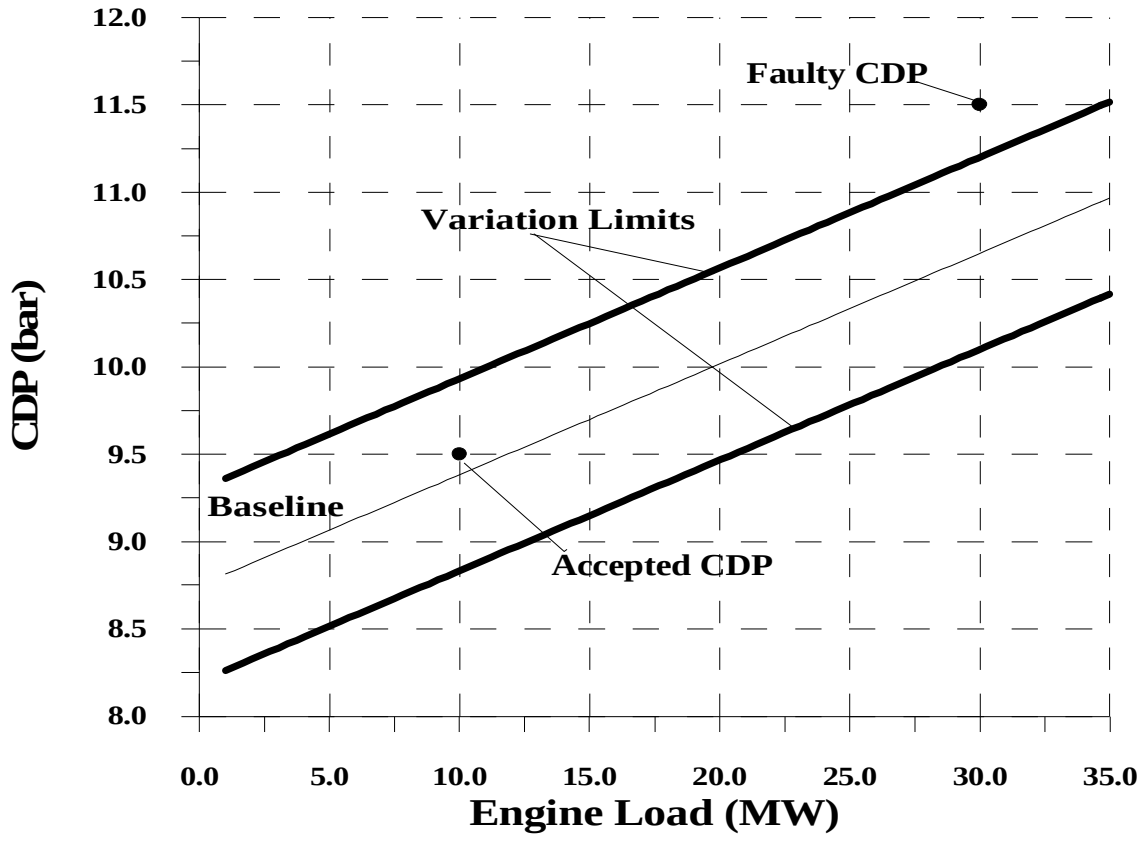


Measurement Validation

Levels of measurements validation checks

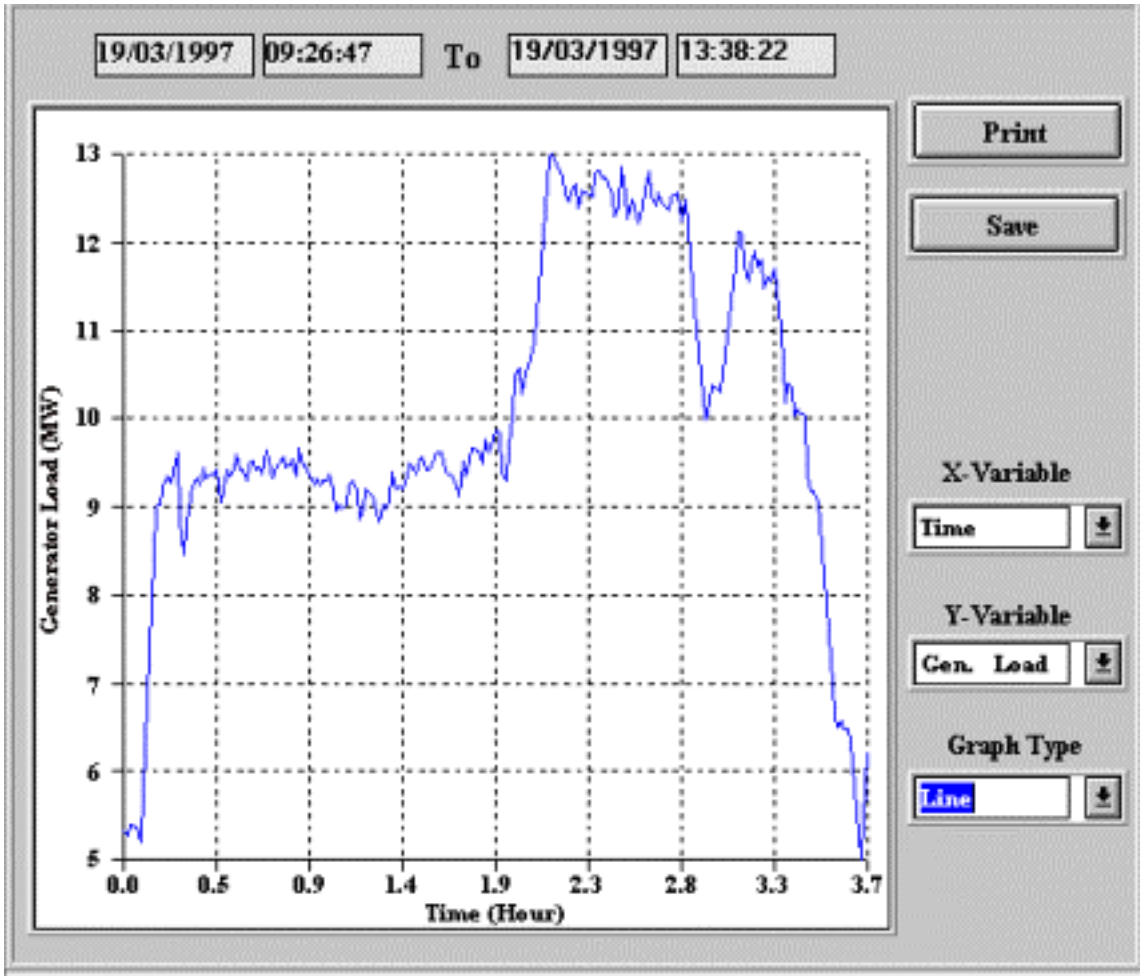
- *Check instrument and physical ranges*
- *Check cross-relation of quantities*
- *Evaluation through thermodynamic analysis*

Example: Compressor delivery pressure at different operating points.



Data Acquisition Module

Example: *Inspection of measurement time evolution*



Thermodynamic Analysis

- **Process measurement data for component condition assessment**

  - Ø *Derive component oriented information, free from influence of operating point or ambient conditions*
  - Ø *Easily interpretable, unified treatment*

- **Study different Operation Scenarios**

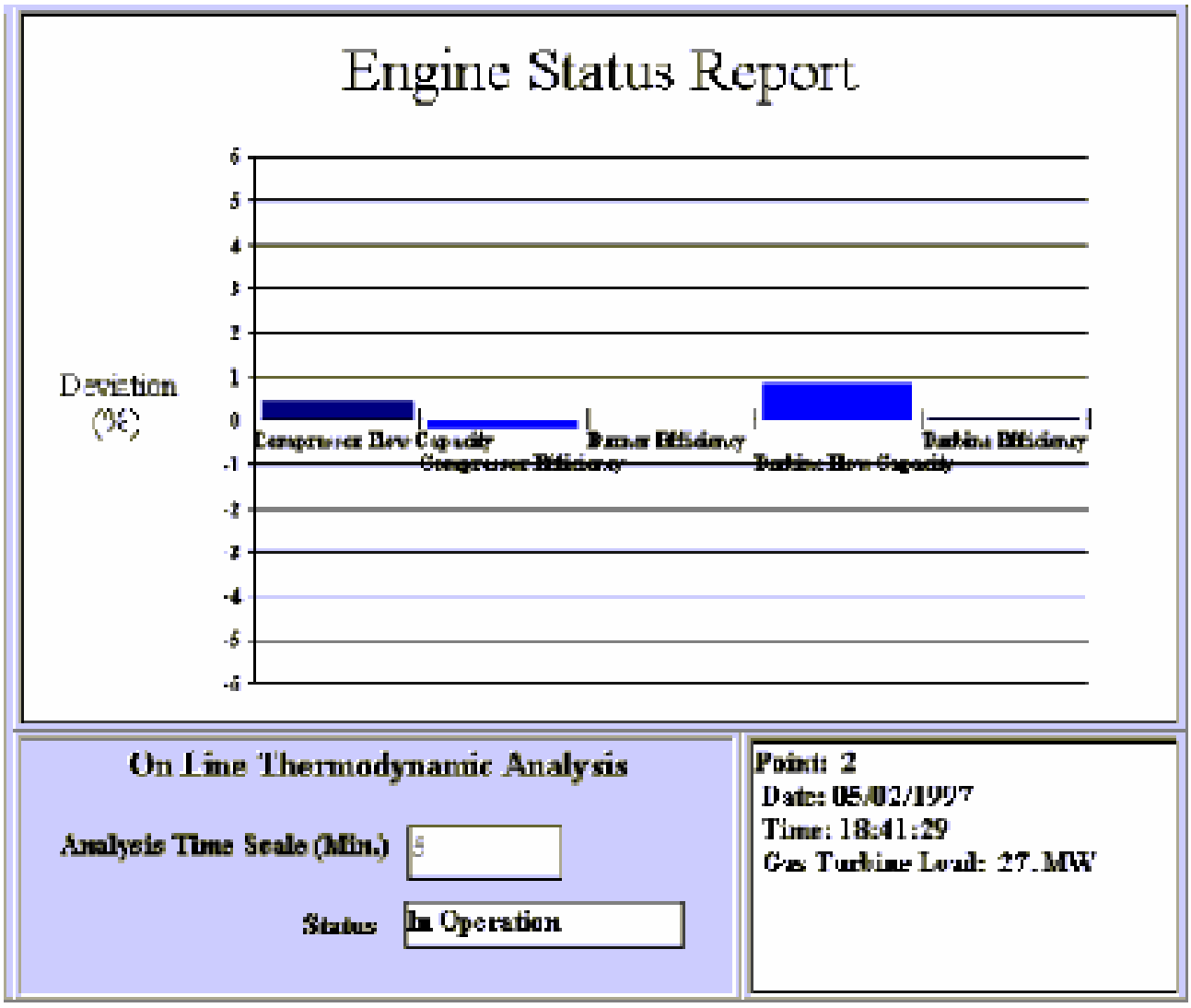
  - Ø *Simulation*

Key Concept:

Modification Factors: $$MF = \frac{X}{X_{ref}}$$

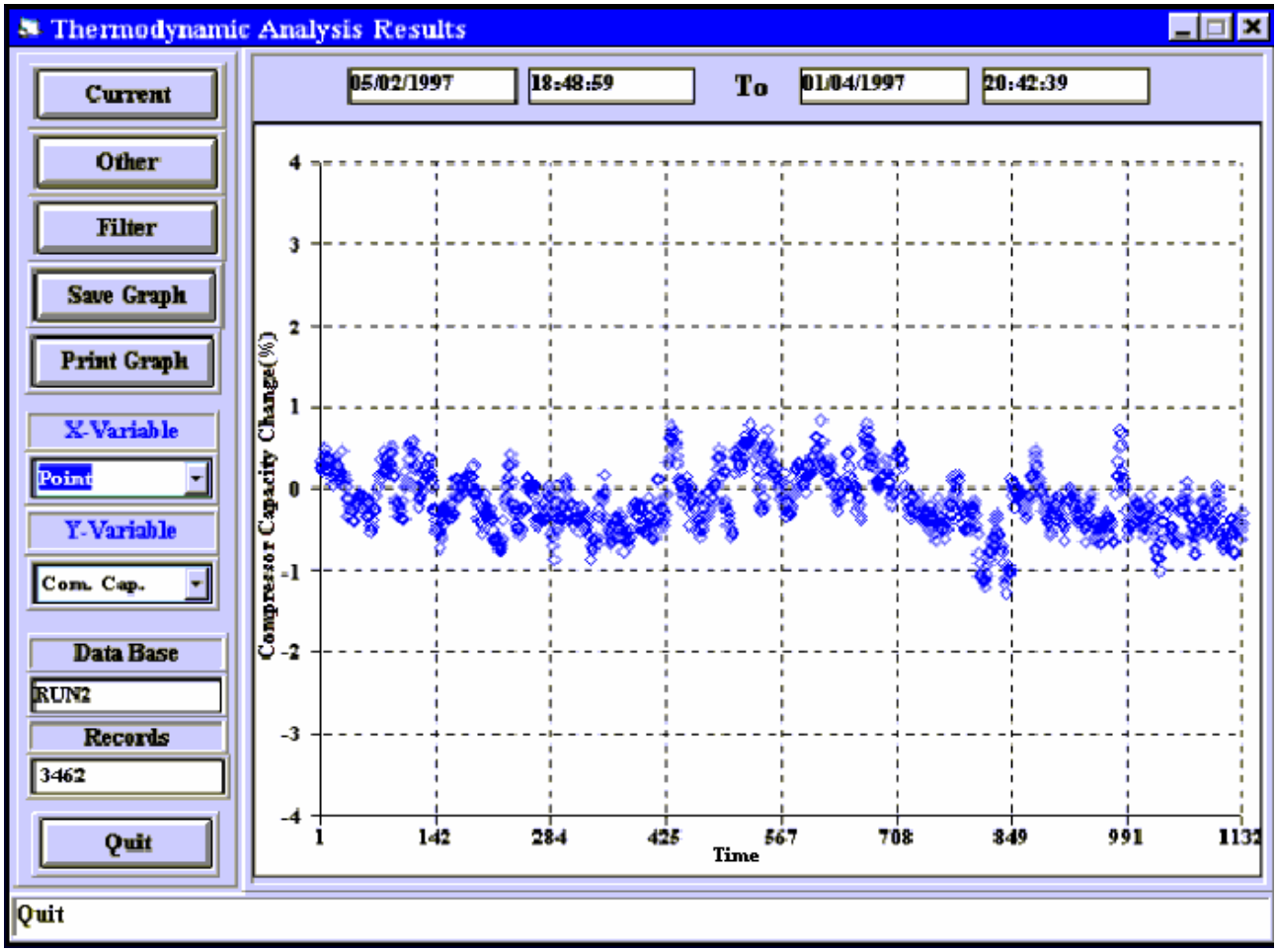
Thermodynamic Analysis

Example: Component Condition Indices.



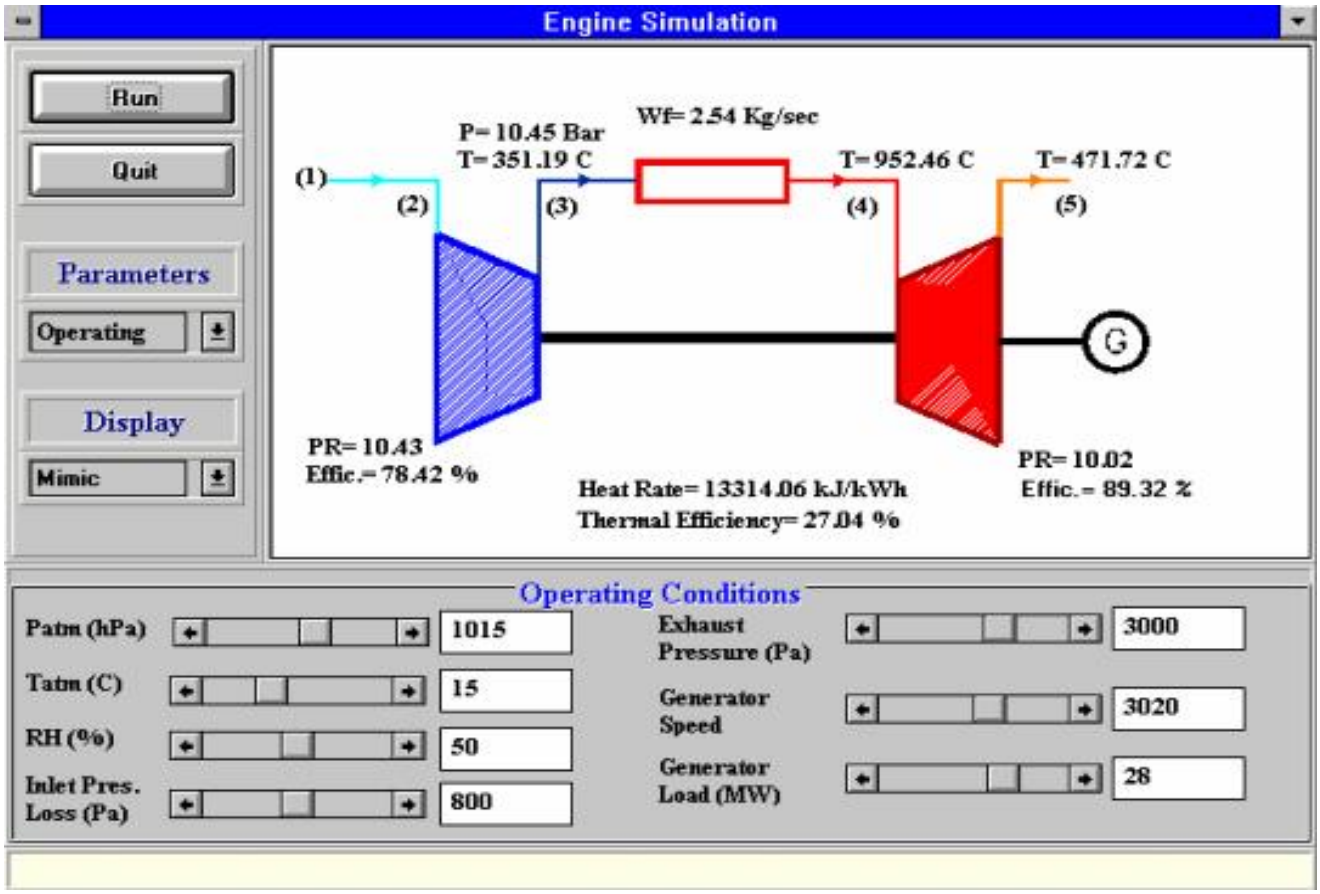
Thermodynamic Analysis

Example: Time evolution of compressor capacity.



Thermodynamic Analysis

Example: Engine simulation screen.



EGT Monitoring

Attention to Most Critical Parts: Hot End

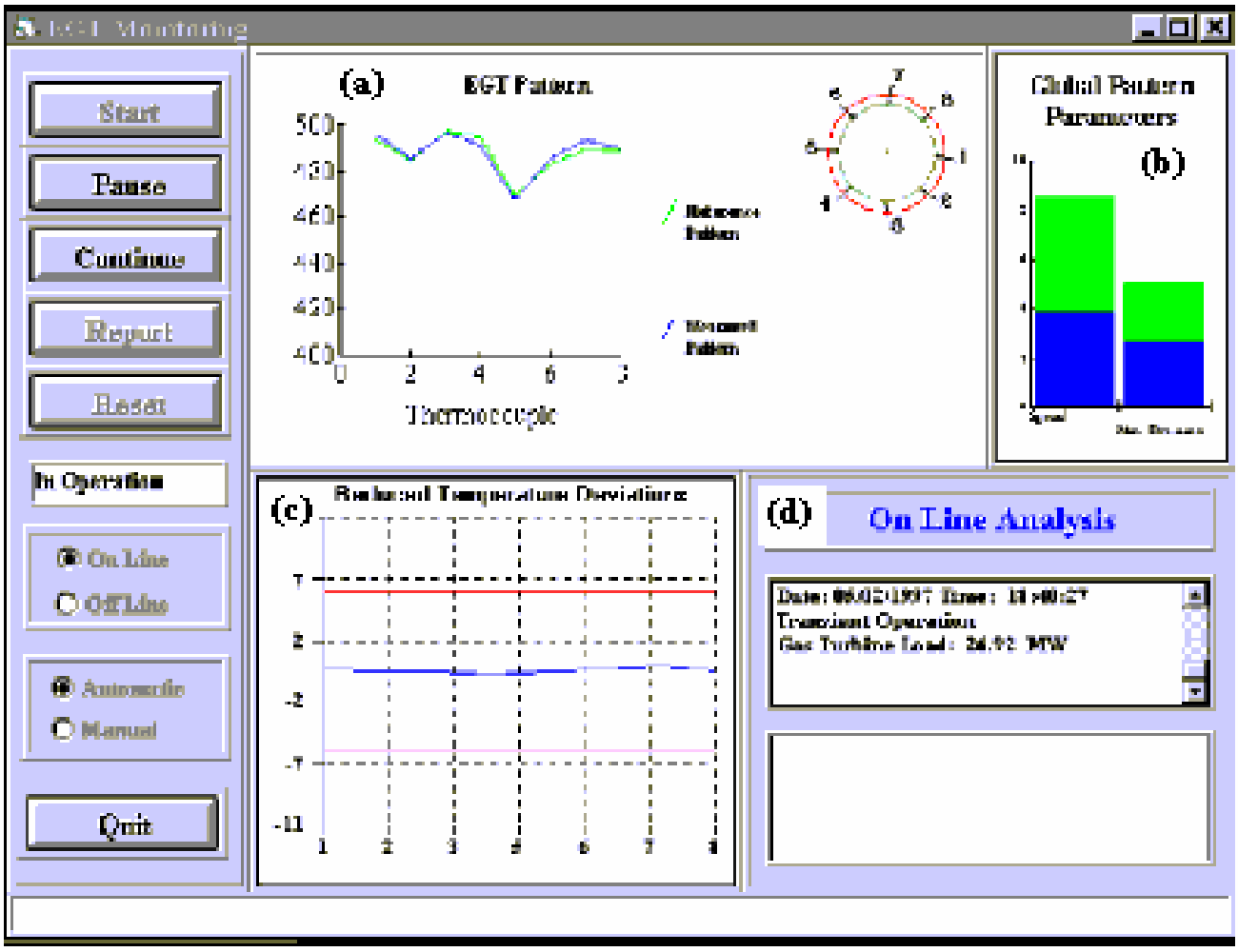
Quantities Observed

- *Global EGT Pattern Properties*
  - Ø *Spread*
  - Ø *Deviation from average*

- *Reduced Temperature Profiles*

EGT Monitoring

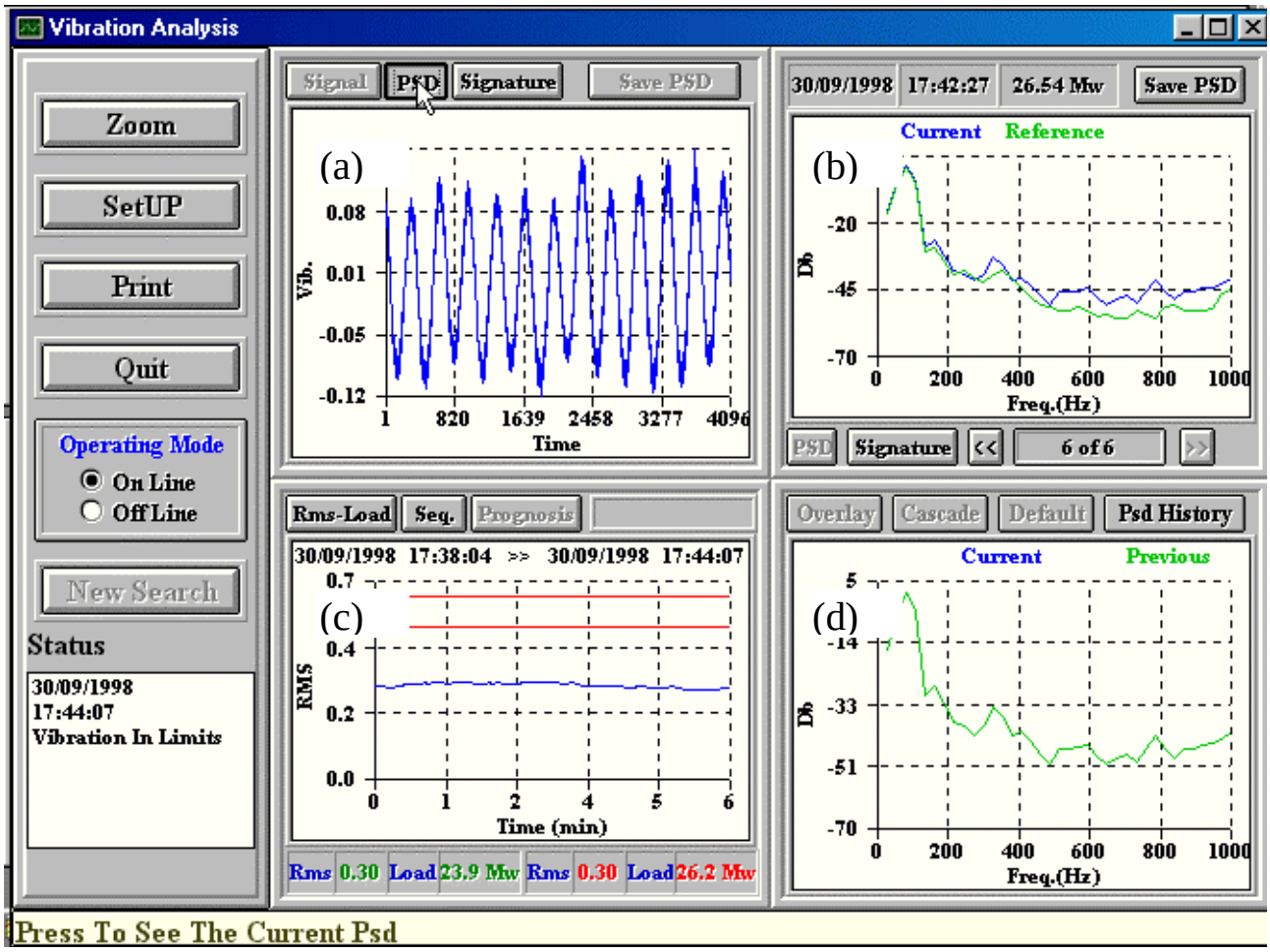
Example of a display screen.



Vibration Analysis

Identify mainly mechanical alterations

Example display from Vibration analysis



The Test Case of an Industrial Gas Turbine

Measurement Set-up

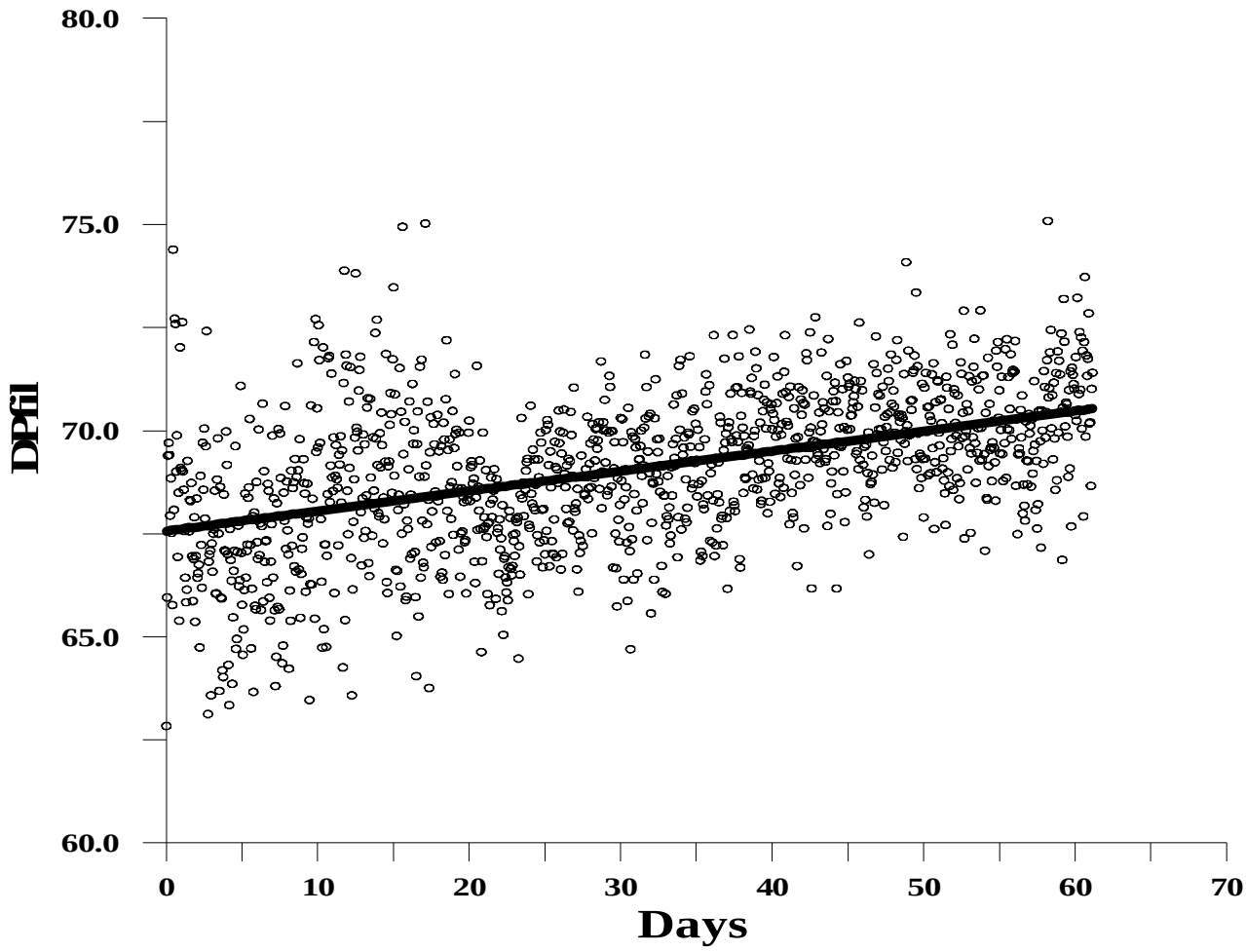
Standard Engine Measurements

- Ø *Generator Load and Speed.*
- Ø *Vibration Overall Level.*
- Ø *Compressor Inlet Temperature.*
- Ø *Compressor Delivery Pressure and Temperature.*
- Ø *Cooling Air Temperature.*
- Ø *Exhaust Gas Temperature (eight thermocouples).*

Additional Measurements

- Ø *Ambient Pressure and Relative Humidity.*
- Ø *Compressor Inlet Total and Static Pressure.*
- Ø *Turbine Outlet Static Pressure.*
- Ø *Engine Outlet Static Pressure (backpressure).*

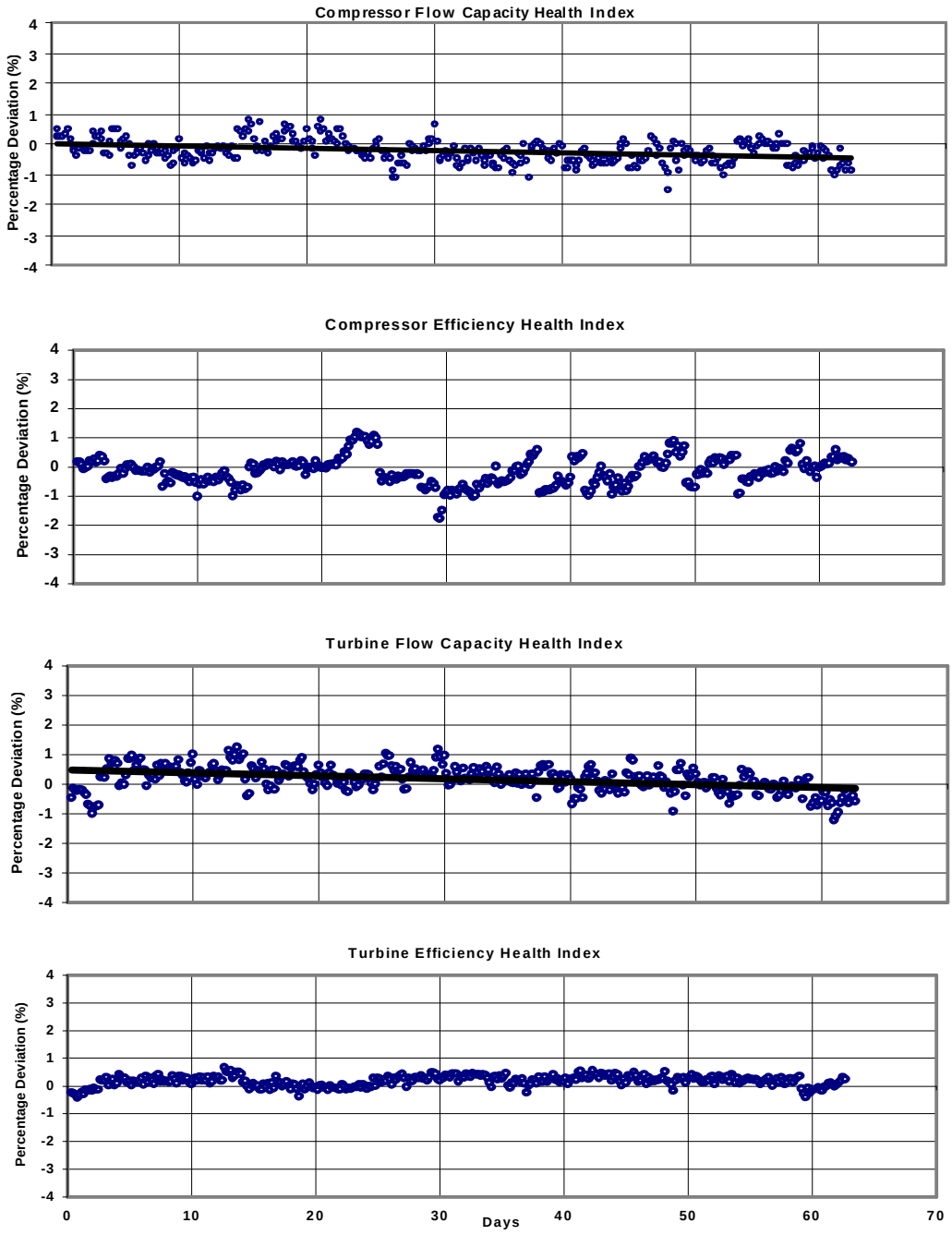
Time Evolution Of Inlet Filters Fouling Coefficient



Filter fouling coefficient: $$DP = \frac{P_{amb} - P_{t,in}}{P_{t,in} - P_{s,in}}$$

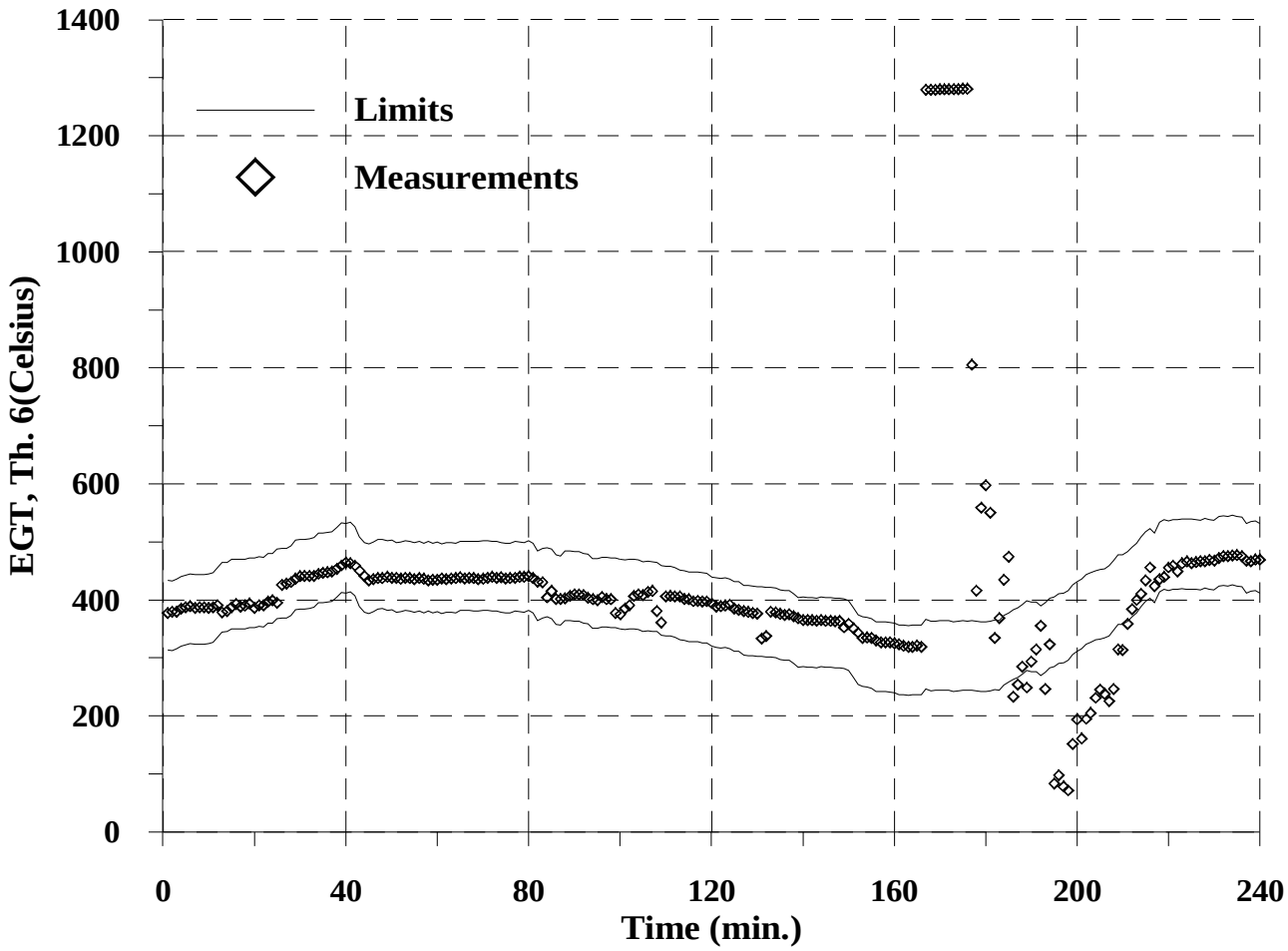
Evolution of Health Indices

'Healthy' operation.



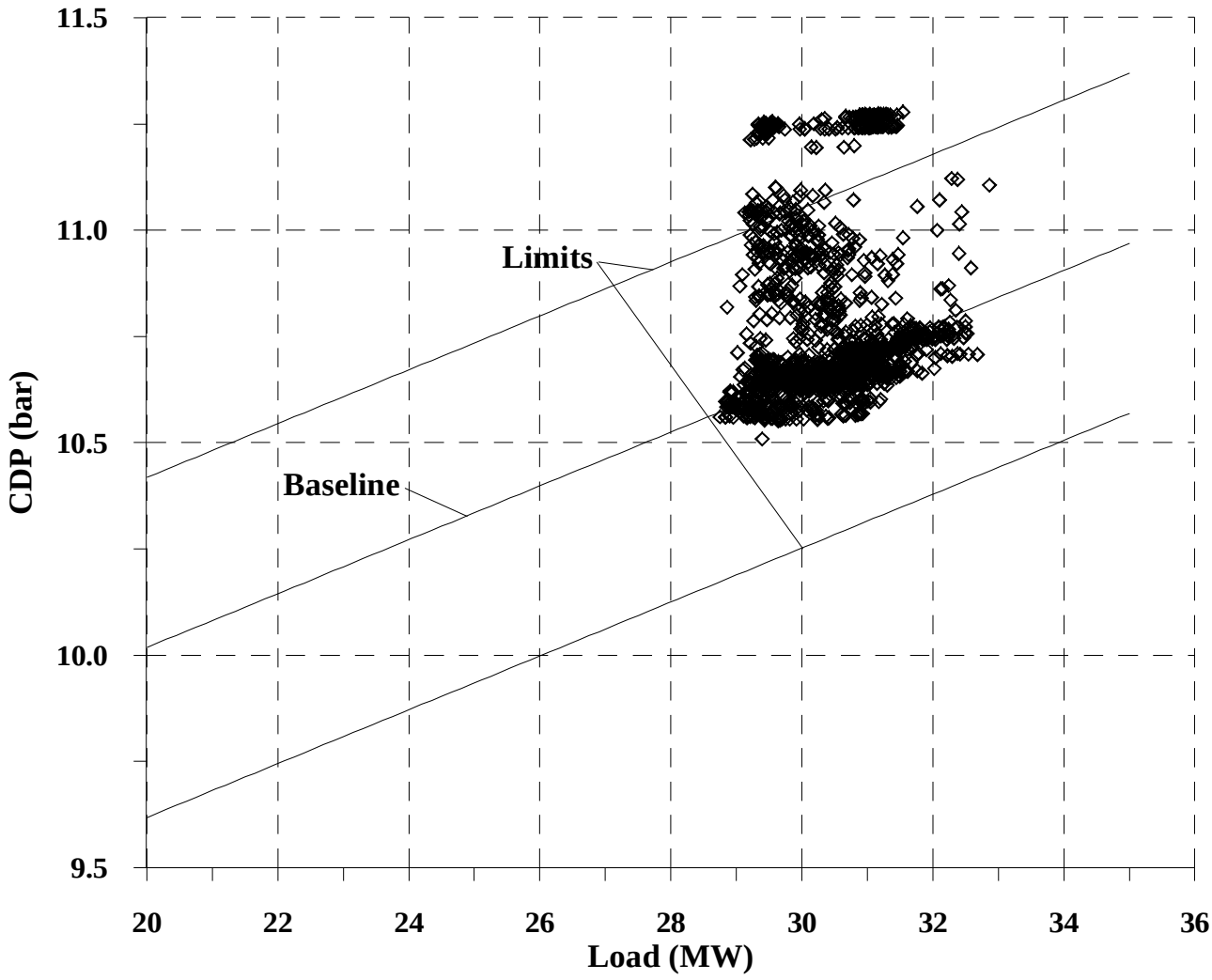
Detection of Sensor Error by Simple Limits Checking

Time evolution of exhaust gas temperature registered by thermocouple 6.



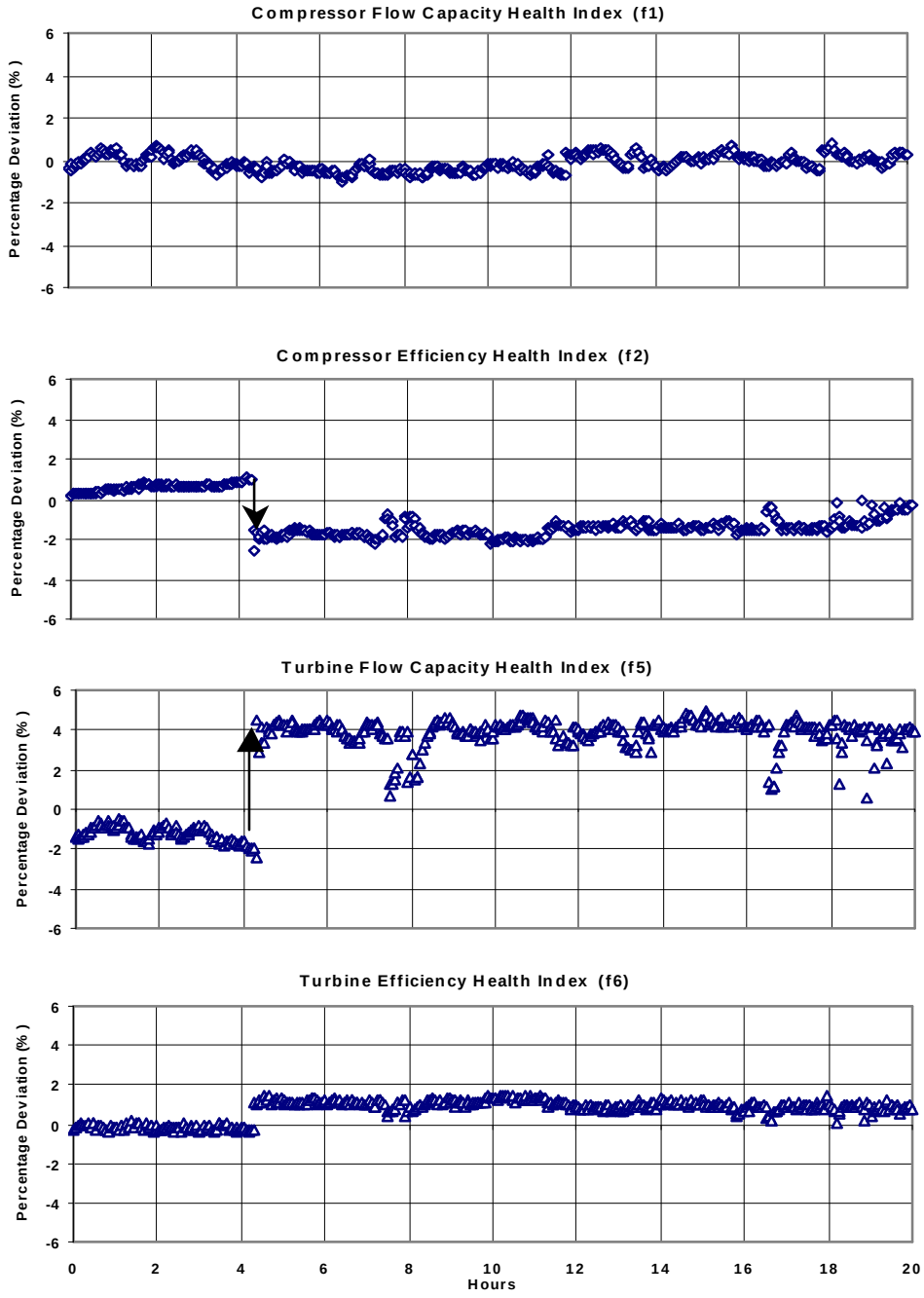
Detection of Sensor Error by Checking Interrelations

Fluctuation of CDP measurements in the case of sensor fault.



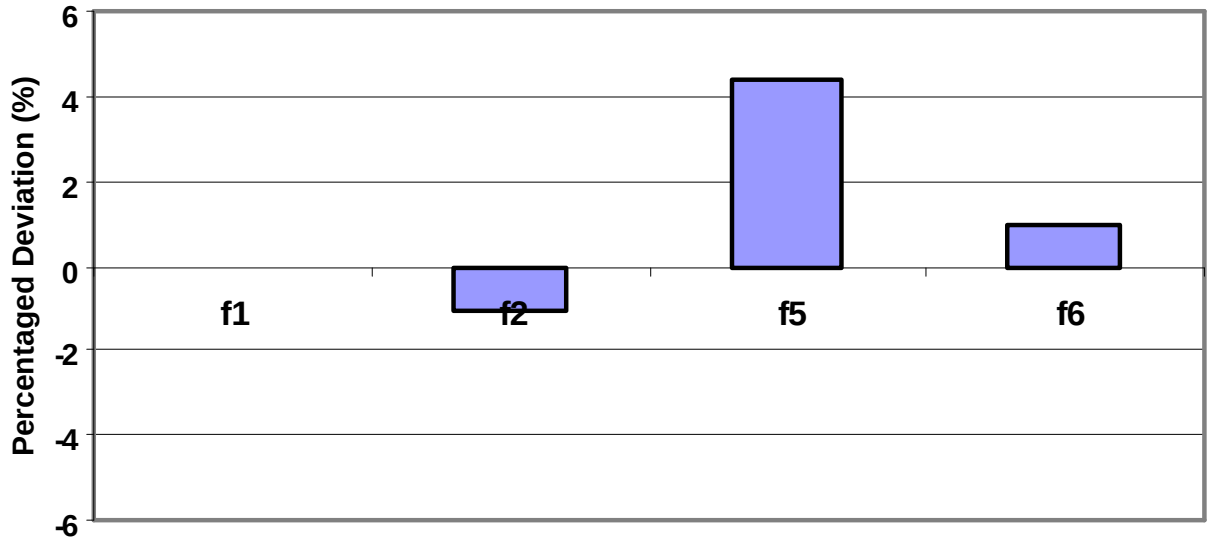
Detection of Sensor Error by Thermodynamic Analysis

Health indices evolution demonstrating CDP fault.



Fault Signature Of CDP Fault.

Produced through the simulation/adaptive mode



SUMMARY-CONCLUSION

- *An integrated monitoring system that can meet current requirements has been developed.*
- *Implementation of the developed system to an operating gas turbine discussed.*
- *The effectiveness of the developed monitoring system was demonstrated by presenting a number of cases of successful fault identification.*
- *Deterioration of either simple-to-observe components, such as inlet filters or turbo machinery components, namely compressor and turbine, is detected and quantified.*
- *Sensor faults could be identified even if they are of such a magnitude that they cannot be detected by simple interrelations of parameters.*