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IMPACT OF DIGITILIZATION ON POWER INDUSTRIES

BY

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Declaration by the Guide

This is to certify that the Mr. AMIT DWIVEDI a student of MBA POWER MANAGEMENT, SAP ID 500071752 of UPES has successfully completed this dissertation report on "**IMPACT OF DIGITILIZATION ON POWER INDUSTRIES**" under my supervision.

Further, I certify that the work is based on the investigation made, data collected and analysed by him and it has not been submitted in any other University or Institution for award of any degree. In my opinion it is fully adequate, in scope and utility, as a dissertation towards partial fulfilment for the award of degree of MBA.

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CHAPTER-1 INTRODUCTION

To stay competitive, companies must continually innovate, improve and streamline their operations. But accurately identifying how and where to improve operations can be extraordinarily challenging if the data that holds the answers is scattered among different incompatible systems, formats and processes.

Enter the PI System and its ability to collect, analyse, visualize and share large amounts of high-fidelity, time-series data from multiple sources to people and systems across all operations. By accessing key data and insights, the PI System has helped leading companies deliver greater operational improvements and breakthroughs that lead ultimately to comprehensive business transformation.

1.1 Overview: -

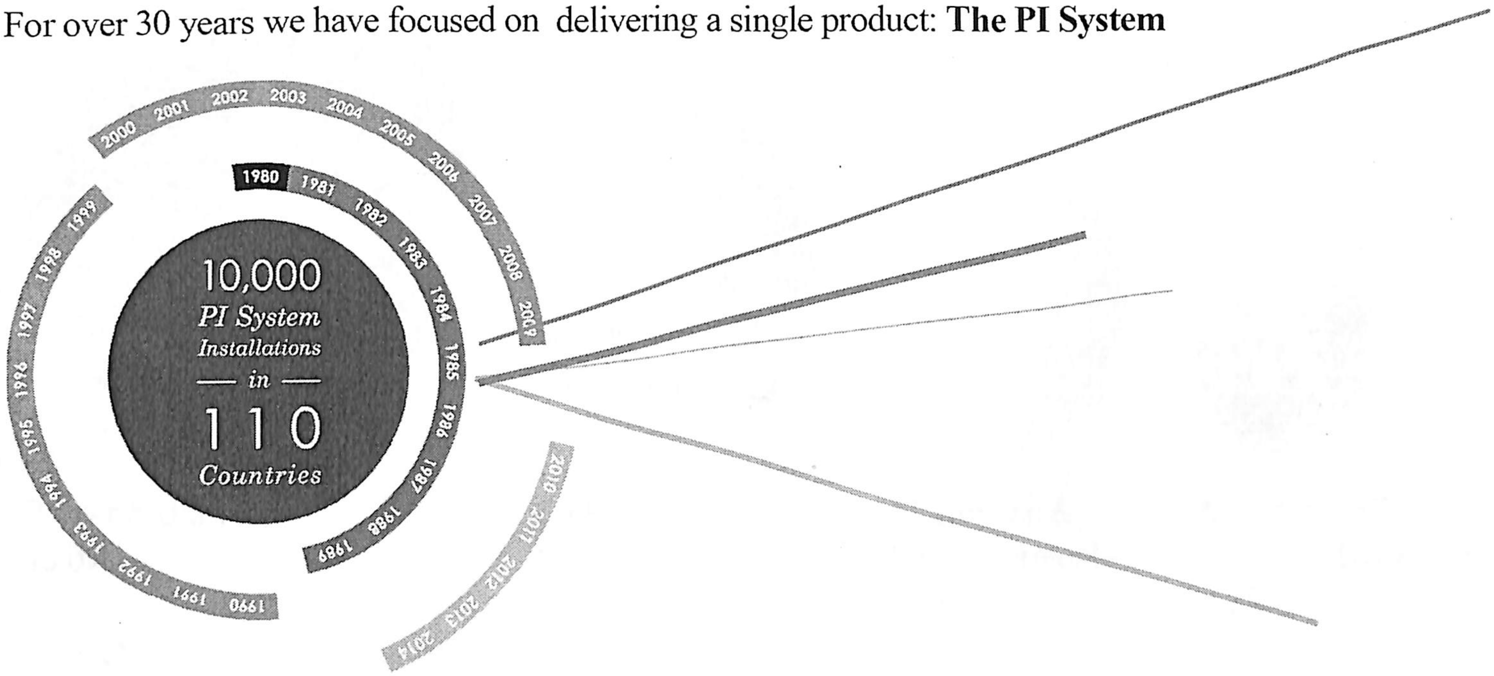
In the competitive power-generation market, power utilities are focused on optimizing their performance while minimizing their operational costs to deliver low-cost, high-quality energy to their customers. However, there needs to be a balance in the trade-offs between performance, operational costs and risks. When it comes to fossil generation, performance optimization is directly related to operations cost. An important parameter of performance optimization is heat rate. The PI System can be the center piece of a heat-rate improvement program, performing the following operational roles:

- Calculating the heat rate and associated parameters: The PI System can perform heat rate and most other performance calculations to monitor most of the controllable costs using PI Asset Analytics.
- Serving as a monitoring and visualization tool: The heat rate and controllable losses can be displayed in real time with the capability to generate trends and perform root cause analysis.
- Assisting with reporting: The PI system has an add-in to export data into Microsoft Excel called PI Data Link. This tool can be utilized to extract data from the PI system in a tabular form to be used for root cause analysis and reporting.
- Serving as the data historian for all the parameter inputs and outputs in the calculations: Most inputs in the calculation of the heat rate and associated controllable costs are stored in the PI system and used as input for the calculations. The calculation results can also be written to the PI system for historical trending, reporting and root cause analysis.

An important benefit of using PI Asset Analytics is that these calculations can be created easily and quickly in a template and applied to various units in one step, saving configuration time and ensuring a uniform application of the calculations across the generation fleet. In addition, there is a discussion on data mining and reporting, which are important aspects of a heat rate improvement program.

The PI System connects sensor-based data, operations and the people who rely on data to manage process efficiency, asset health, quality and resource management. The PI System works through server-based technology and makes historical and real-time data instantly accessible to users wherever they are.

For over 30 years we have focused on delivering a single product: **The PI System**

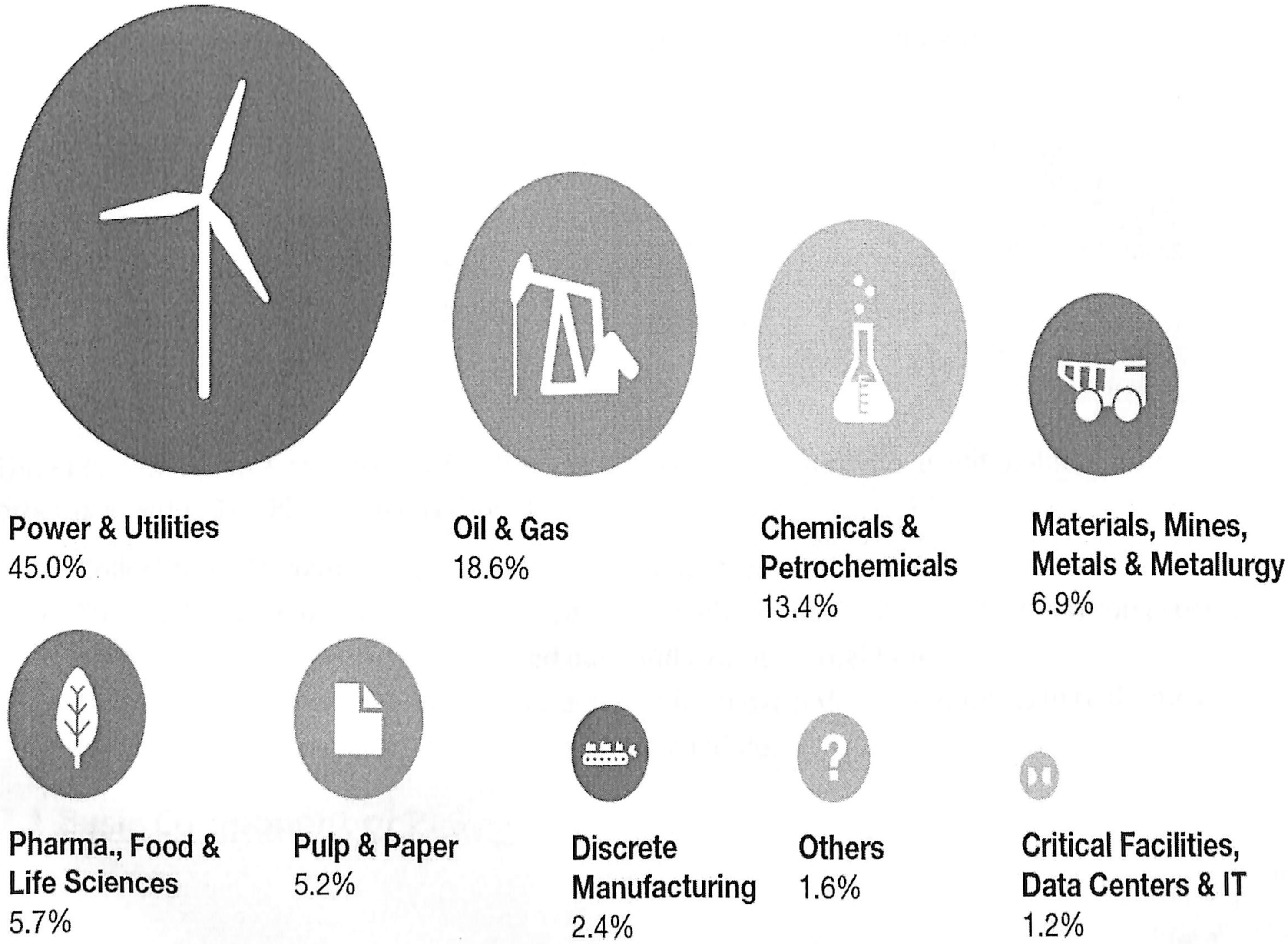


1.2 Background: -

OSIsoft is a company whose purpose has remained constant since 1980: to empower our customers' business transformation by delivering greater value into the enterprise.

At OSIsoft, supporting our customers' journey to operational excellence is at the core of what we do. It's why we constantly evolve the PI System™ open infrastructure for the people, industries and organizations we serve. It's why we support every customer's systems and team with our experienced engineers. It's why we've grown from a small data historian software company to a global leader in operational intelligence. And why 95% of our first customers still use the PI System today.

Who uses the PI System?



1.3 Purpose of the Study: -

Understanding the aspects in power industry where digitalization is applied.

Which type of failure can be diagnose through digitalization.

How to minimize unexpected failure through digitalization.

Study of impacts of digitization on the power industry performance.

How to increase reliability and availability of equipment's with the use of digitalization.

Identifying barriers to digitization in power industry.

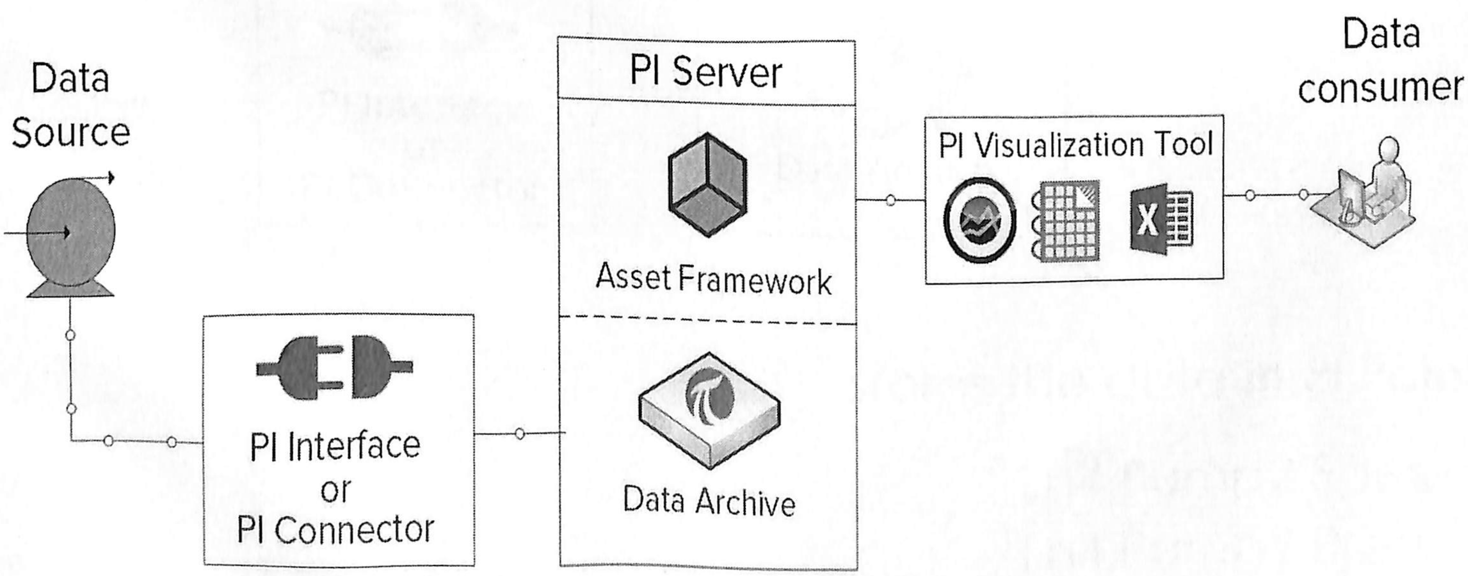
CHAPTER-2 LITERATURE REVIEW

The PI system is all the software in between data source and data consumers.

The PI system is like a baby from which we need to watch its every move and maintain the process healthy. The PI system has three layers.

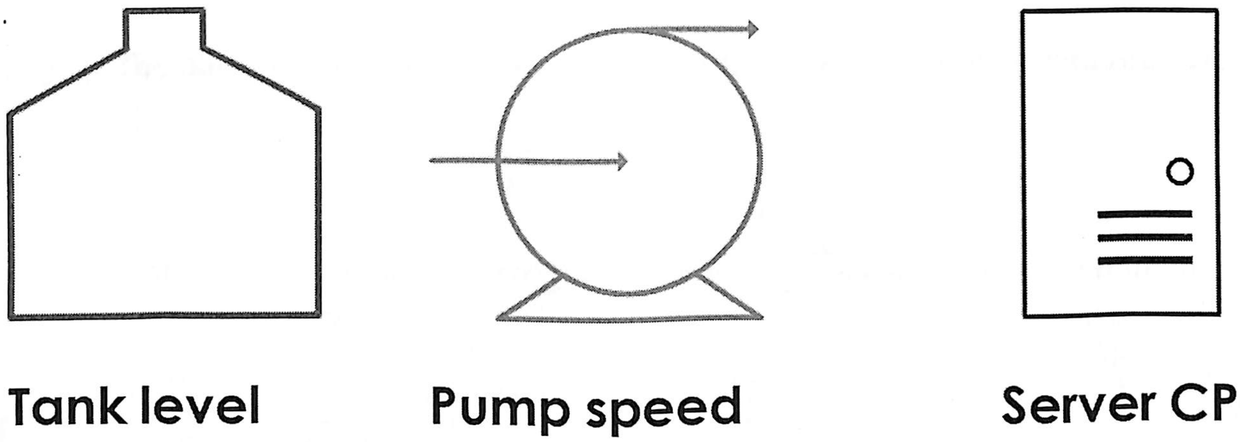
1) Collect the information: - Collect time series data from any source
2) Store & Enhance the information: - We stores high frequency data in digitalization process. Now provide context to our collected data and runs it on real time analysis.
3) Deliver the information: - We can access data from excel Visualize process in real time and we can monitor the data from anywhere and anytime.

2.1 Basic Component of PI System: -

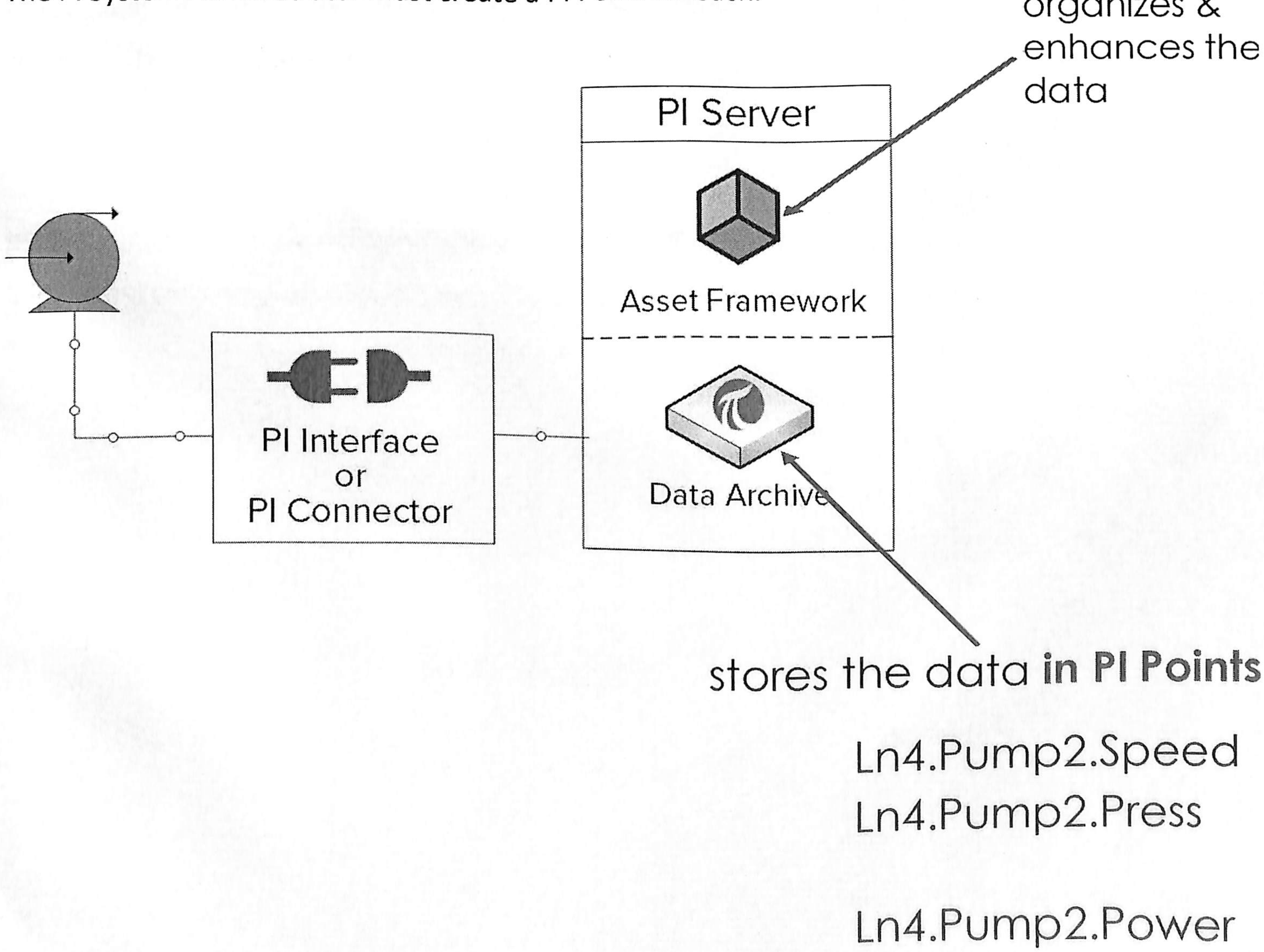


2.2 PI Point: -

Any data that has a changing value over time can be collected and stored in the PI Data Archive.



The PI System Administrator must create a PI Point for each.



2.3 PI Point attributes: -

Name: The name of the PI Point, which must be unique within the PI Data Archive.

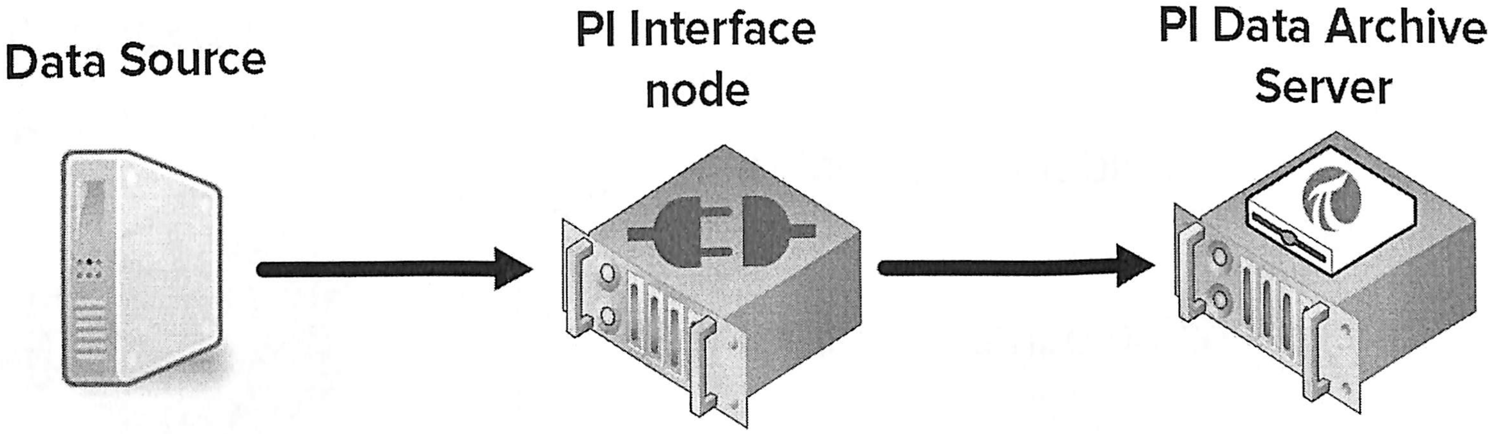
Description: A free text field attached to a PI Point, often used to enter a human friendly description of the PI Point.

Point Type: This attributes defines the type of data that is stored in the PI Data Archive.

Point Source: This attribute commonly specifies which PI Interface is collecting the data for the PI Point.

Chapter 3: Research Design, Methodology and Plan

PI INTERFACE: -



1. Reads from Data Source
2. Timestamps data (if not already)
3. Formats data
4. Applies Exception
5. Sends data to PI Data Archive

Data Source: -

Siemens PLC 412-2

Schneider PML 3710ACM

Johnson Controls Metasys System

A web page

Text files (HINT: what is the most common type of text file encoding?)

Common PI Interfaces: -

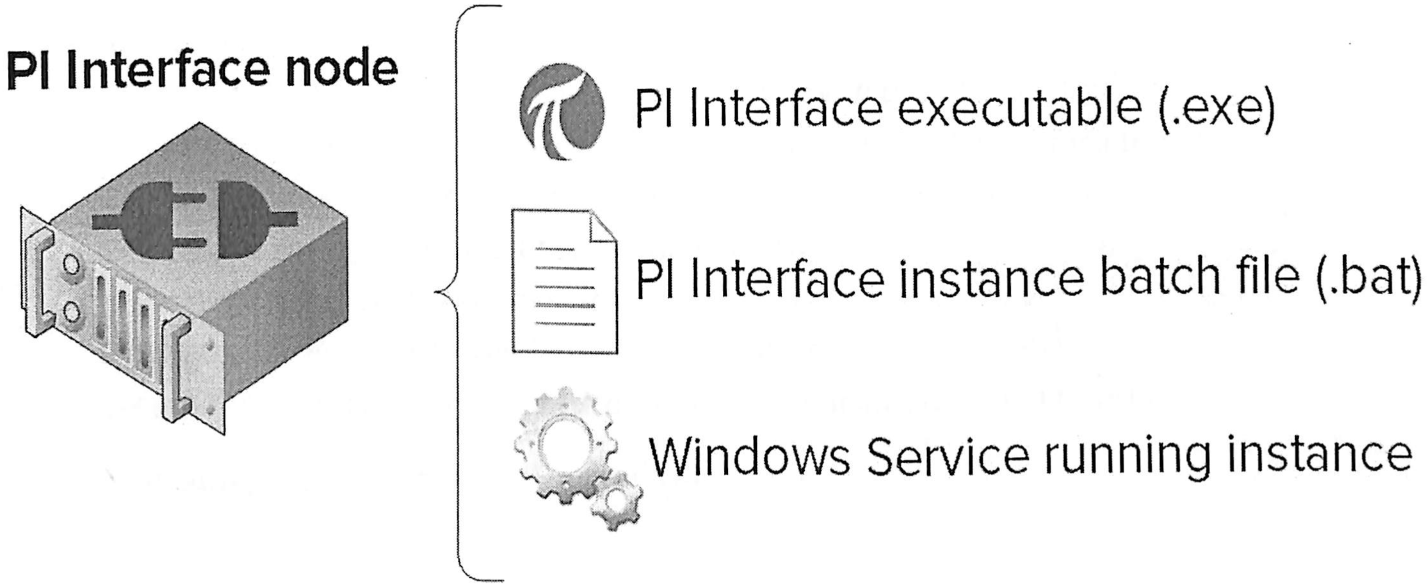
OPC DA Server-------------------- PI Interface for **OPC DA**

ASCII File--------------------------- PI Interface for **UFL**

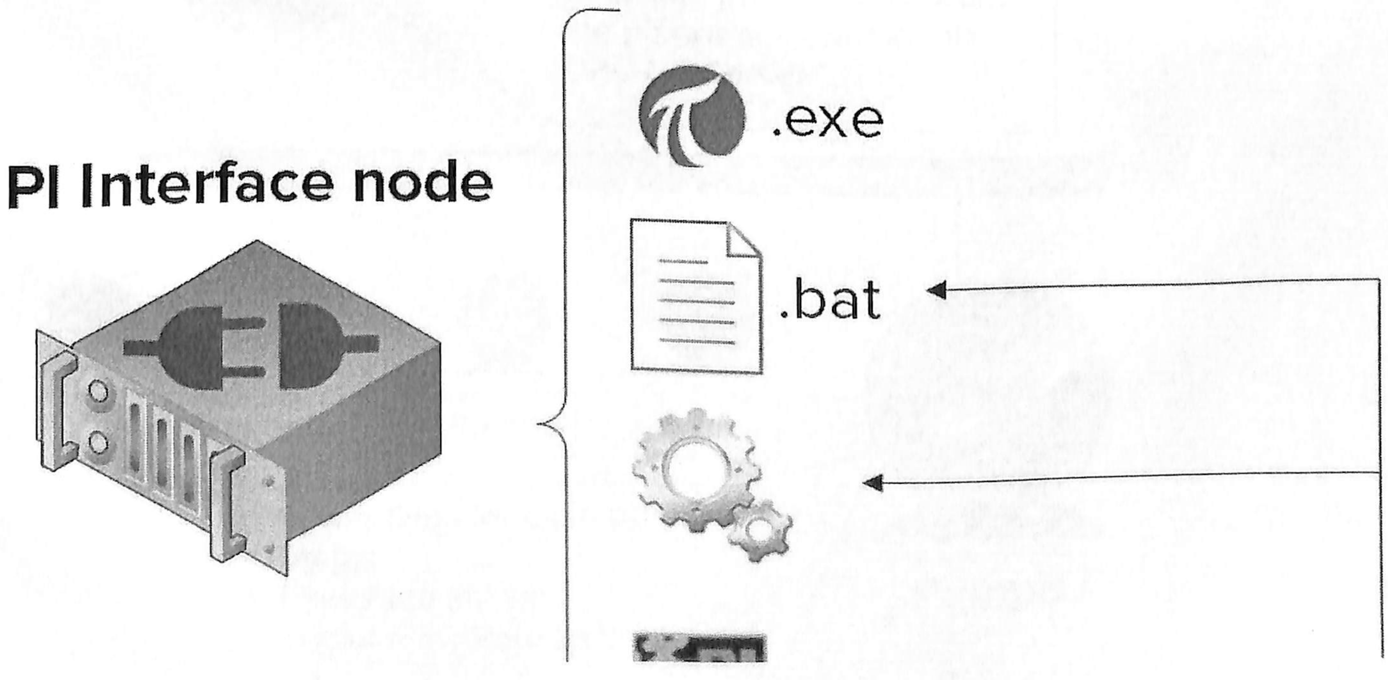
Relational Database------------ PI Interface for **RDBMS**

Modbus Device------------------ PI Interface for **Modbus**

PI Interface components: -



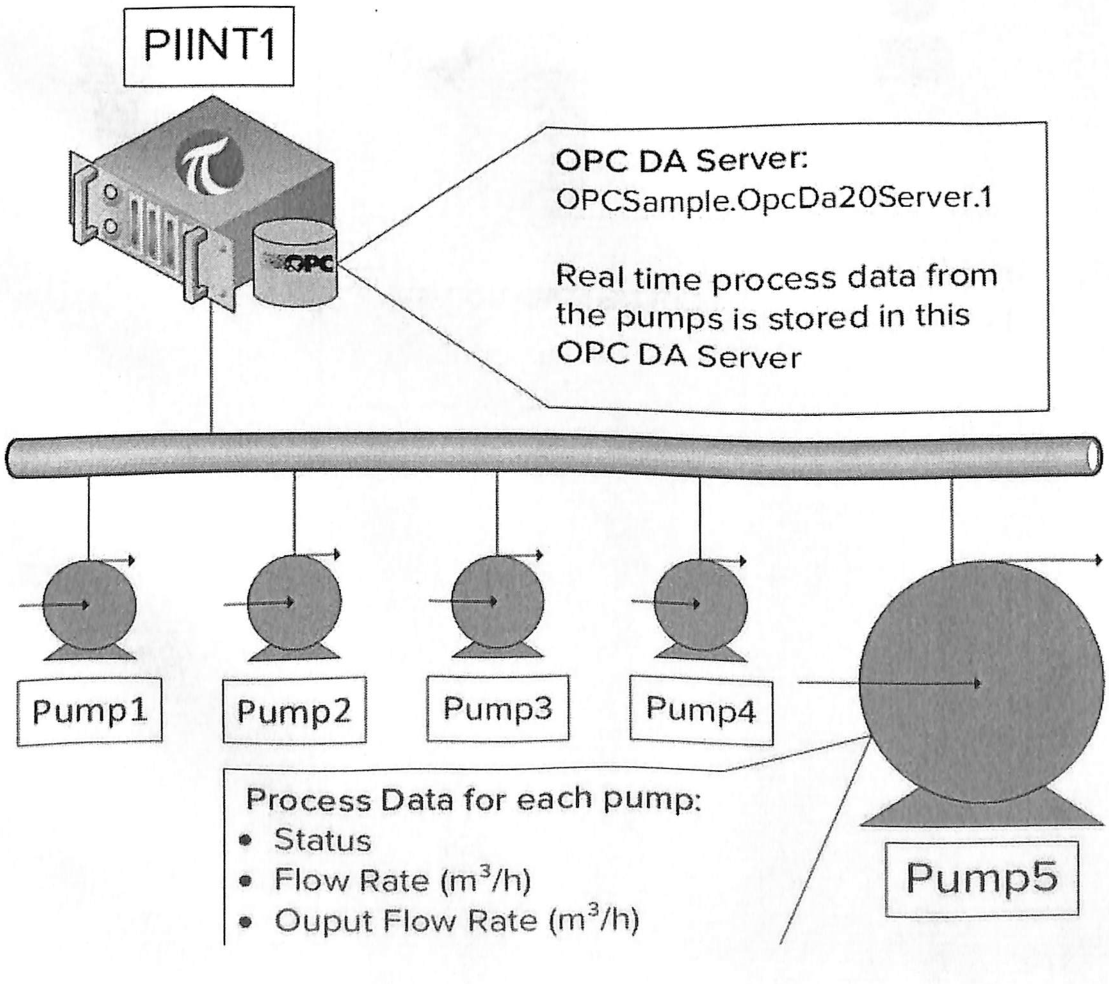
PI Interface Configuration Utility: -



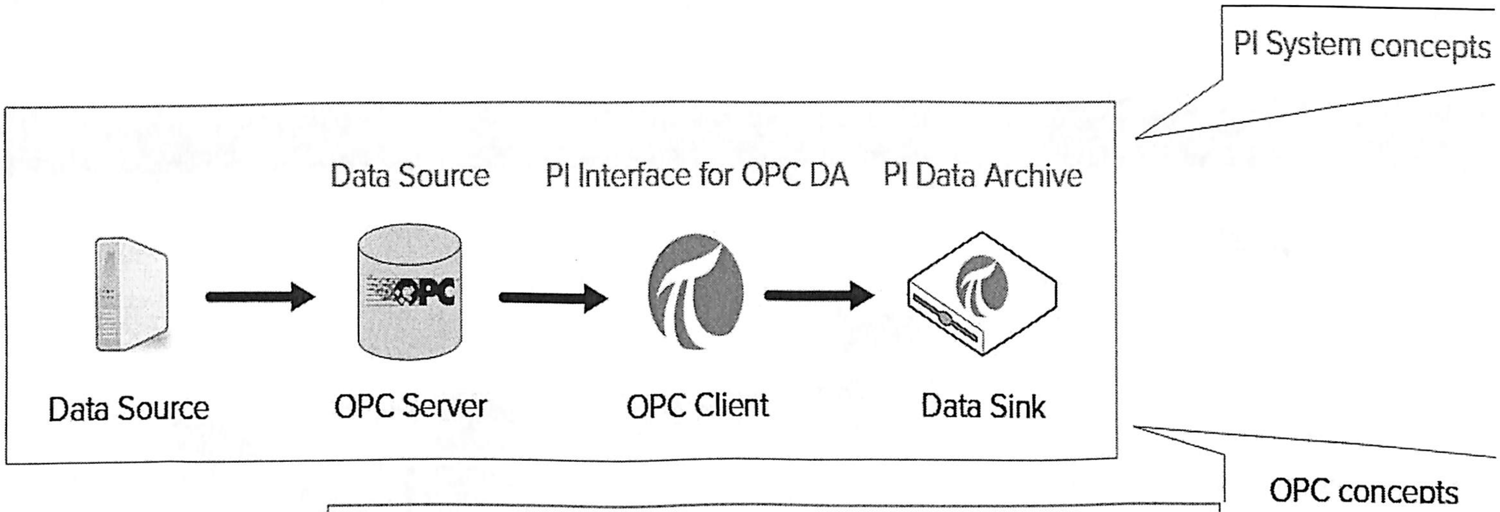
PI Interface Installation methodology – Basic: -

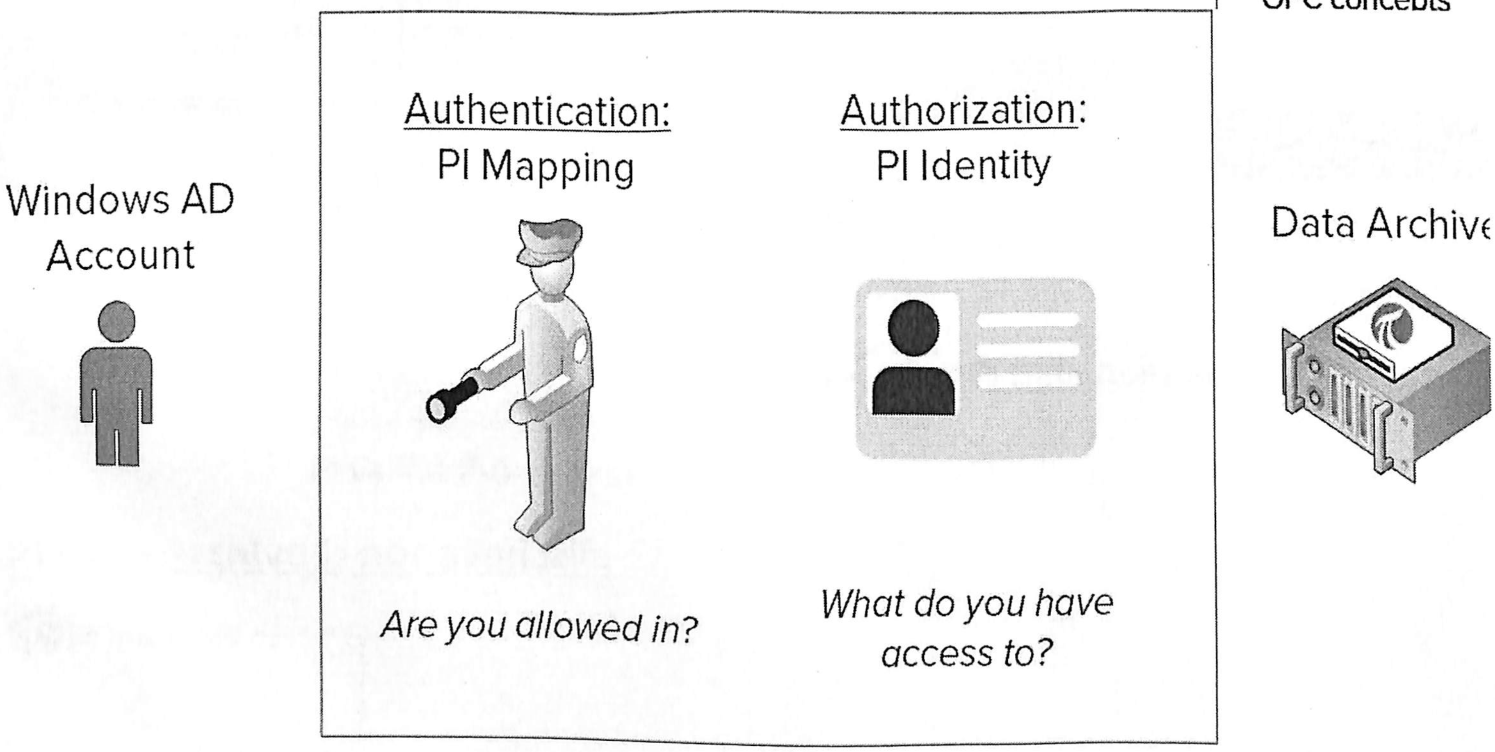
- Choose a PI Interface for the data source.
- Choose a PI Interface architecture.
- Install the PI Interface, the PI API and the PI ICU.
- Validate that the PI Interface can communicate with the PI Data Archive.
- Validate that data is available on the data source for the PI Interface to read.
- Configure security for the PI Interface on the PI Data Archive.
- Create and configure an instance of the PI Interface.
- Create PI Points for the PI Interface.
- Configure buffering with the PI Buffer subsystem.
- Create PI Interface Health Points to monitor the health of the PI Interface.

Install and configure a PI Interface for OPC DA: -



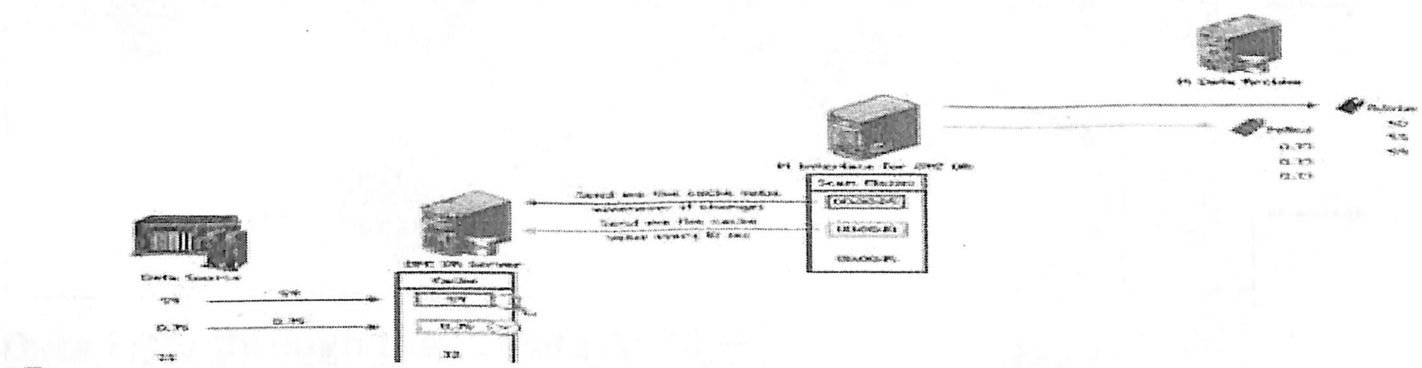
<u>OPC DA Server</u>: - OPC DA is a standard communication protocol developed for the industrial automation industry.



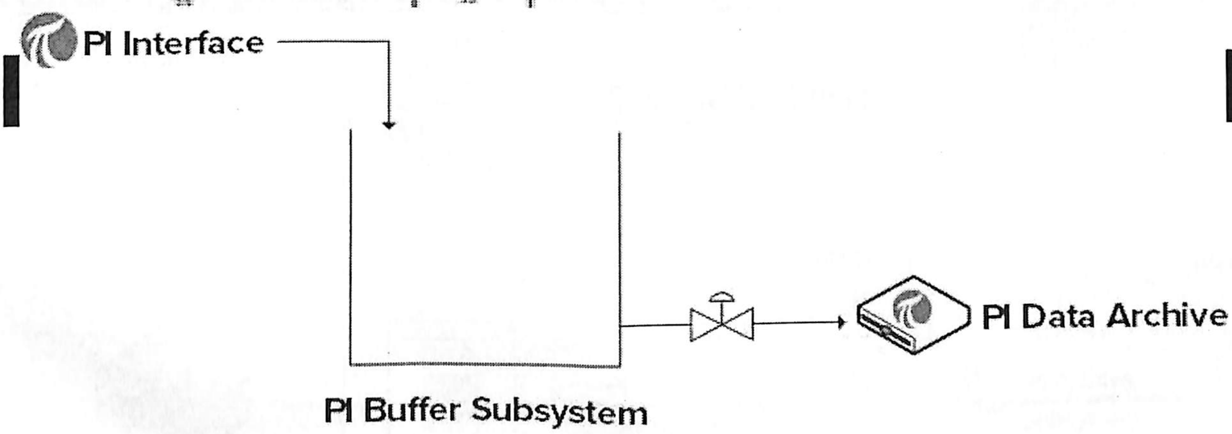


PI Point types for the PI Interface for OPC DA: -

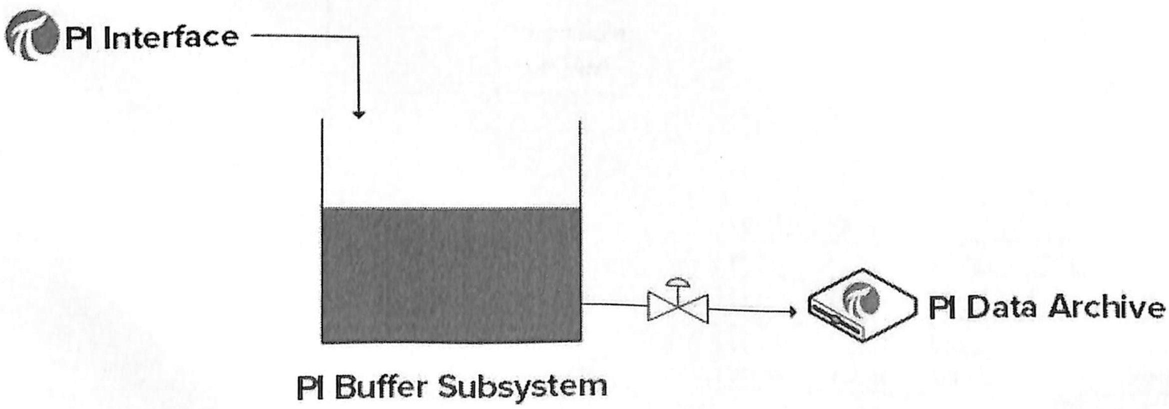
[redacted]



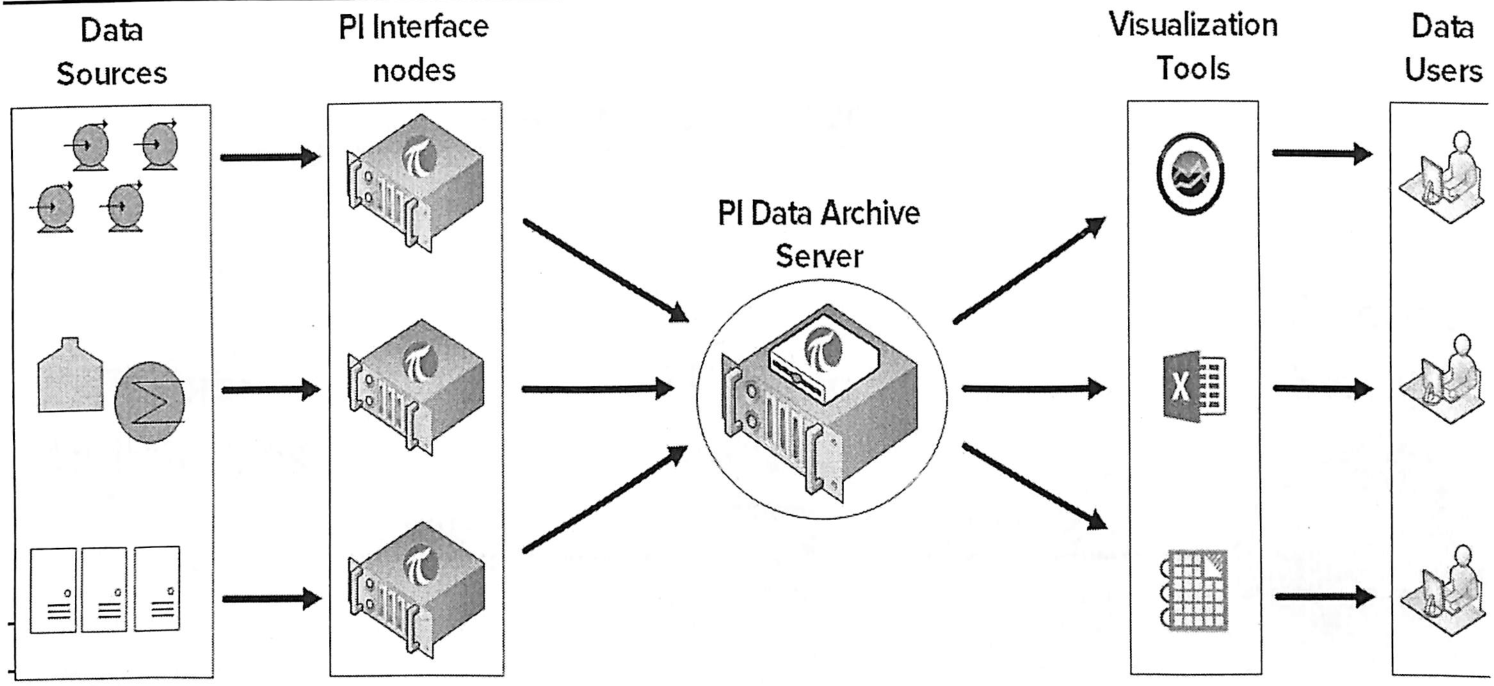
[redacted]



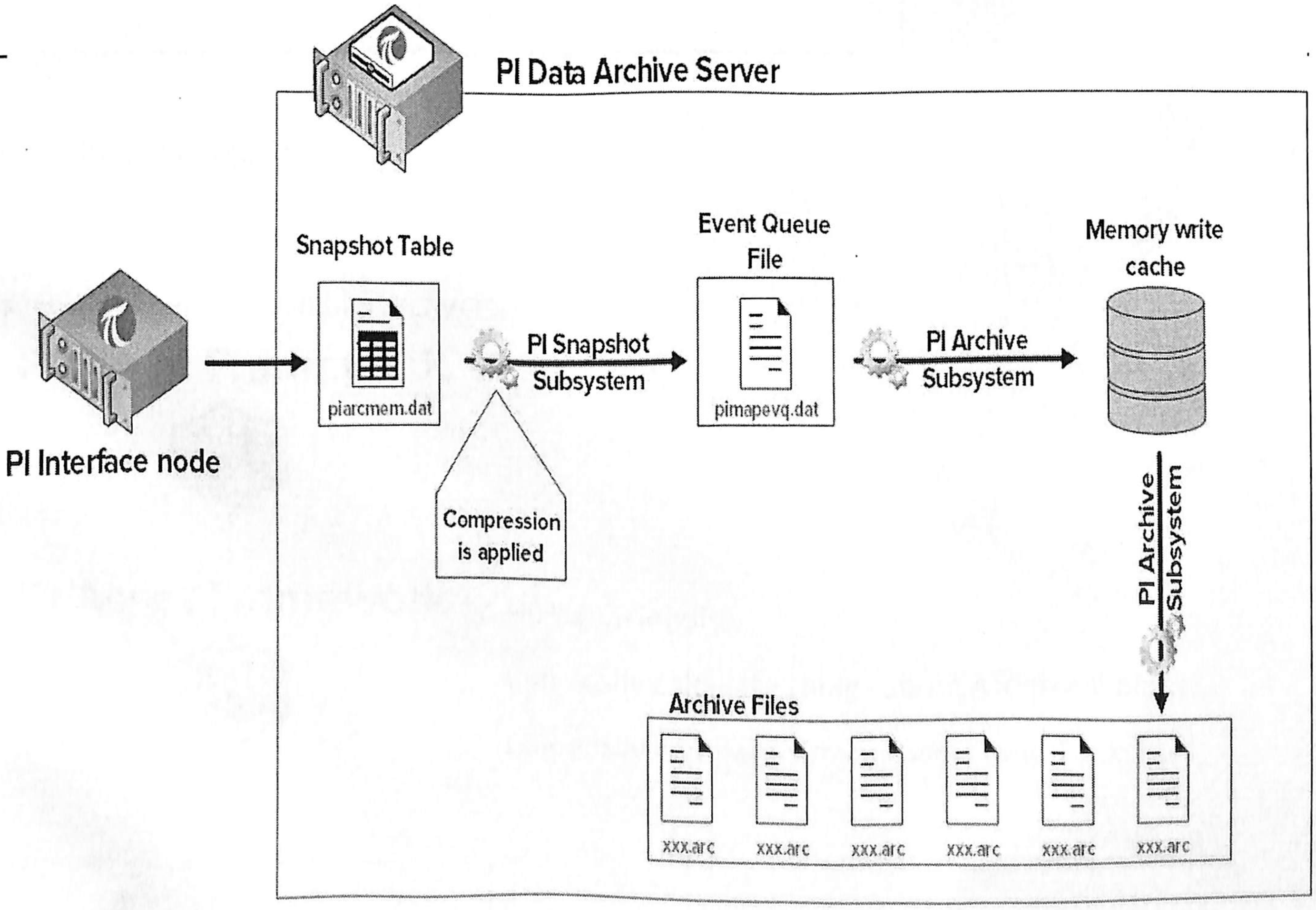
PI Data Archive is not available



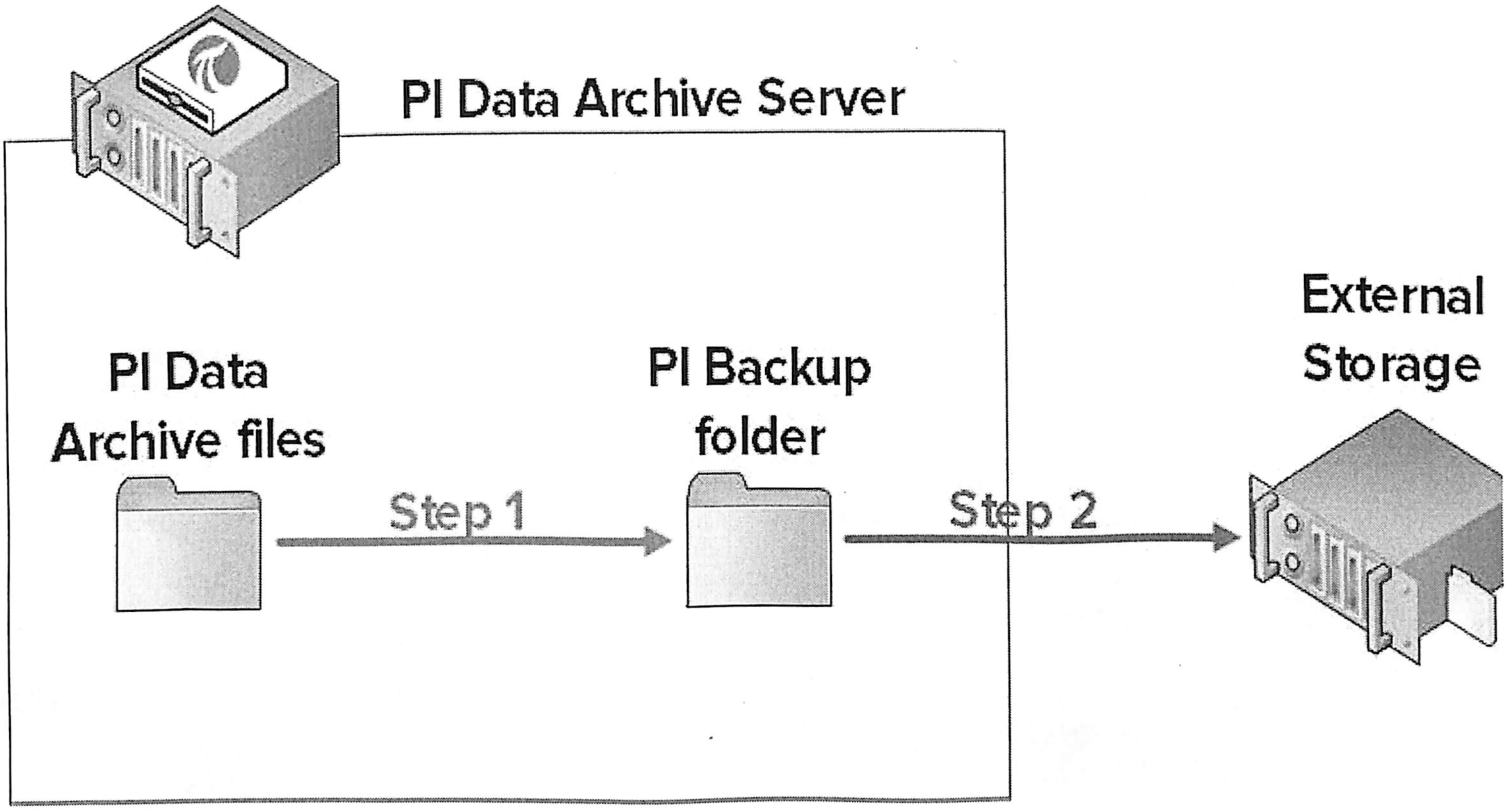
Role of the PI Data Archive: -



Data Flow through the PI Data Archive: -

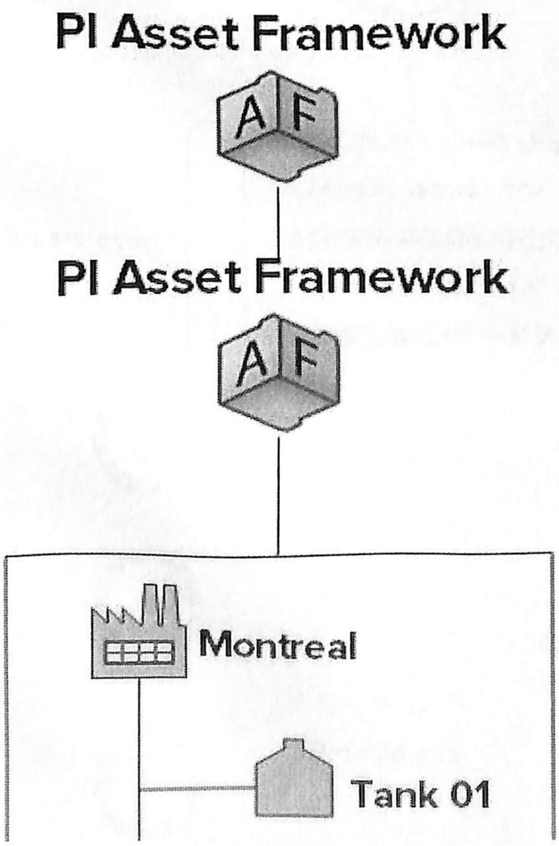


PI Backup Strategy: 2-step back up: -



How data is organized: -

Assets are organized in a hierarchy

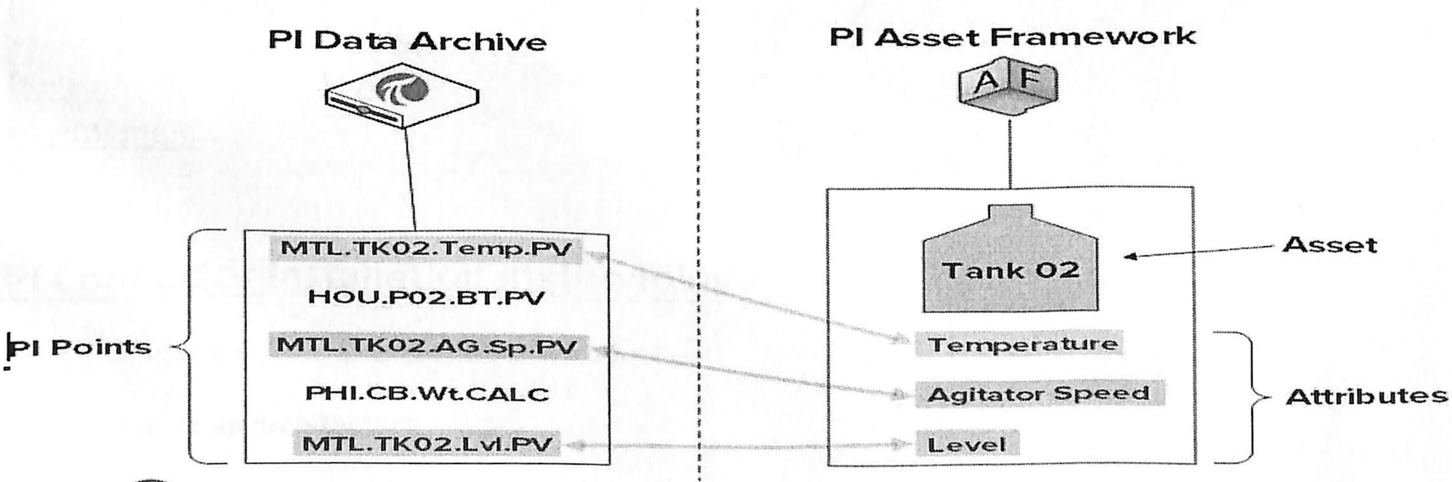


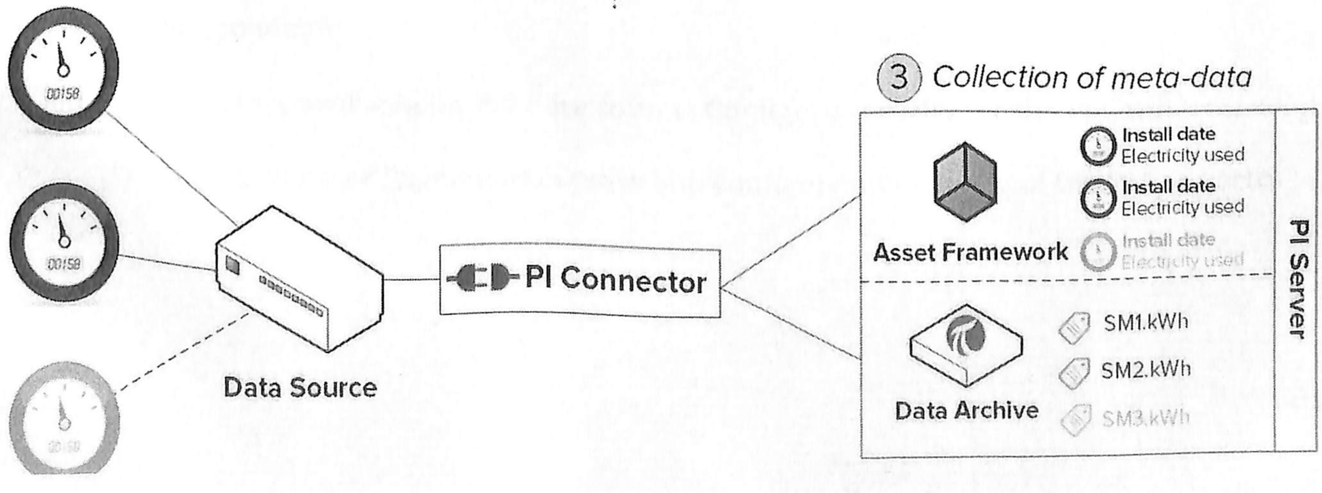
Human friendly

Can easily calculate things about Montreal plant

Can easily compare similar assets (e.g. Tanks)

The data is organized under assets





PI Interface vs. PI Connector:-

Description	PI Interface	PI Connector
PI Points	Must manually create PI Points	Auto-discovers & creates as needed
Buffering	Must manually configure buffering	Automatic build-in buffering
Data types	Time-series data only	Time-series & meta data (Asset structure, Event Frames)
Administration	Locally using the PI ICU	Locally & Remotely using a web UI
Configuration changes	Interface restart required	Does not require restart
Number of instances	Once instance per data source	Only one instance on a server for multiple data source
Exception filtering	Yes	No
Development environment	PI API	AF SDK

PI Connector Installation methodology: -

- Choose a PI Connector for the data source
- Choose an architecture
- Install the PI Connector
- Validate that data is available on the data source. Configure security for the PI Connector on the PI Data Archive & PI Asset Framework. Create and configure an instance of the PI Connector

Chapter 4: Findings and Analysis

Overview: -

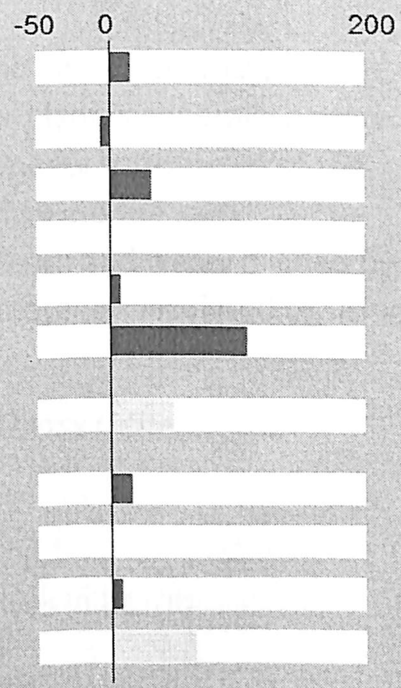
If the heat rate on a typical 350 MW fossil steam generating unit increases just **one percent**, depending on the fuel cost it could cost over **half a million dollars per year**. This illustrates the importance of monitoring the heat rate and making the adjustments necessary to keep it as low as possible. The important thing to remember is that heat rate is directly related to the cost of operation.

Therefore, it is essential that these calculations use the actual temperatures, pressures and mass flow rates measured in real time so that the heat rate calculation can change in real time. Once the unit heat rate and all the controllable efficiency losses are calculated, these metrics need to be monitored in real time and analyzed using historical data to identify the root cause of deviations affecting unit performance. The below figure represents a typical heat rate and controllable loss monitoring screen that can be developed to visualize the unit performance and help quickly identify anomalies. The losses can be presented using PI bar graph dynamic multi-stating where they can be presented using different colors proportional to the size of the loss. For example, in the below figure, the condenser back pressure is easily identified as the largest loss. The PI system can then be utilized to root cause analysis to mitigate the effect.

Gross Gen. 350 MW
Net Gen. 332 MW

Unit 1 - Heat Rate and Controllable Loss Summary

	Actual	Target	HR Effect Btu/kWh
Throttle Temperature	990 Deg F	1000 Deg F	12
Throttle Pressure	2005 psig	2000 psig	-3
Hot RH Temperature	970 Deg F	1000 Deg F	35
RH Pressure Drop	10.1 %	10.0 %	5
RH Attemperation	0 klbh	0 klbh	0
Condenser Back Pressure	1.5 in hg	1.0 in hg	100
Turbine Efficiency - HP	83.0%	85.0%	32
IP	88.0 %	89.0%	16
Gas Outlet Temperature	300 Deg F	295 Deg F	10
Feedwater Heater Effect	450 Deg F	451 Deg F	1
Auxiliary Power	18.55 MW	18.5 MW	3
Steam and Water Loss	25 klbh	0 klbh	75
Total Losses			286
Net Heat Rate	9999 Btu/kWh	9699 Btu/kWh	300



The following section describes how to calculate the heat rate and associated controllable efficiency losses of a fossil fueled boiler-steam turbine unit using the PI system. It discusses the following topics related to heat rate and associated controllable efficiency loss metrics:

- Heat Rate Calculation
- Controllable efficiency losses and calculations
- Data Mining, Visualization and Reporting
- Heat rate and controllable loss explanations provided in the Appendix

Heat Rate Calculation: -

There are two basic methods for calculating heat rate. The first is as follows: $Unit\ Heat\ Rate = Fuel\ Input\ (Btuhr) Gross\ Generation\ (kW)$.

The numerator represents the fuel flow in lb/hr multiplied by the heating value in Btu/lb. Note that if the fuel is natural gas, the flow could be in ft3/hr and multiplied by the heating value in Btu/ft3. Oil flow could be in gal/hr and multiplied by its heating value in Btu/gal. The denominator is the generator power output. The heat rate could be gross or net depending on whether or not the auxiliary power is subtracted from the gross generation.

Because the coal flow is often difficult to measure accurately in real time, this could lead to an inaccurate calculation of heat rate. Note that natural gas and oil flows are generally more accurate, thereby increasing the accuracy of the above calculation.

The heat rate may also be calculated another way which can lead to increased accuracy, especially for coal fired plants. The feed water water flow in the power plant is generally a more accurate measurement than coal flow. If we calculate the amount of energy transferred to the water/steam in the boiler and divide it by the boiler efficiency, it should yield the same approximate heat rate value. The amount of heat transferred to the steam and water divided by the generation is commonly called Turbine Cycle Heat Rate. This parameter is calculated by using the following formula:

$$Turbine\ Cycle\ Heat\ Rate = (mfw\ (hso - hfw) + mhrh\ (hhrh - hcrh))Gross\ Generation$$

Where:
mfw = Feed water mass flow rate in lb/hr
hso = enthalpy of steam entering the high pressure turbine control valves in Btu/lb
hfw = enthalpy of feed water entering the boiler economizer in Btu/lb
mhrh = hot reheat steam flow in lb/hr
hhrh = enthalpy of hot RH steam in Btu/lb
hcrh = enthalpy of cold reheat steam in Btu/lb

The Turbine Cycle Heat Rate equation calculates the amount of available energy that the steam turbine cycle converts into power. The turbine cycle heat rate divided by the boiler efficiency equals the Unit Heat Rate. Therefore, the Unit Heat Rate formula above can be written as: $Unit\ Heat\ Rate = Turbine\ Heat\ RateBoiler\ Efficiency = Fuel\ Energy\ InGeneration$
The Turbine Cycle Heat Rate, Gross and Net Unit Heat Rates can all be calculated in real time using PI Asset Analytics. PI Asset Analytics has a Steam Table calculation function included that calculates enthalpy, entropy, saturation temperature and pressure and other common parameters necessary to determine the heat rate and turbine efficiencies. The input PI Tags for the equations should be averaged and all pressures should be converted to absolute units. Currently the Steam Table engineering units are only available in SI so the English system values need to be converted to SI. PI Asset Analytics has incorporated a convert function to make this process easier.
PI Asset Analytics employs optional templates to create calculations. The recommended way to build these calculations is in a template for the first unit, rolling out to other similar designed units afterwards. This will save significant modeling time for multiple units in a plant or if the calculations are being performed on a central PI system for several generating units. Another significant benefit of templates is when a change is made to the template, it can be applied to all units (or elements) that are associated with the template at the same time in a single operation. This allows for quicker modifications and helps ensure uniformity of calculations.

A useful method to organize these calculations is to keep the data preparation items such as the absolute pressure adjustments, SI unit conversions and multiple input average results in a separate PI Asset Analytics module. It is a good practice to write the SI conversions and the multiple tag average results to separate PI Tags for use in other calculation modules and to aid in root cause analysis. The figure below shows the unit conversions for steam temperatures and pressures from the English System to SI:

Each tag used in the heat-rate calculation can be time averaged for 1 minute using the *TagAvg* function to help stabilize it but still provide a fairly rapid indication of any issues. Once all the data preparation is complete, the heat rate can be calculated. The below figure shows a heat-rate calculation module where the Turbine Cycle Heat Rate, Gross and Net Unit Heat Rates are calculated. The Turbine Cycle Heat Rate calculation is shown. Notice that once the Steam Table function has determined the parameters such as enthalpy, they can be converted from SI to English units if desired.

It should be noted, that the current version of PI Asset Analytics Steam Tables does not yet determine the thermodynamic properties of subcooled water, such as the feedwater temperature entering the boiler. This can be determined using a PI Asset Framework (AF) Table lookup of the feed water temperature at a constant pressure. The subcooled liquid properties are scheduled to be added in a future version of the PI Asset Analytics. When this occurs, the feedwater enthalpy can be determined using the steam tables and the table lookup will no longer be necessary.

Depending on the accuracy desired, the boiler efficiency can either be a static input to a PI tag or it can be calculated in real time using the methods described in References 3 and 4. If a static value is utilized, it could be verified monthly and adjusted as necessary.

Controllable Loss Calculations: -

Throttle Temperature: -

Throttle temperature is the temperature of the steam entering the high pressure turbine. If the steam temperature is lower than target, the available energy will be reduced, increasing the heat rate. The loss represents the difference between the target throttle temperature and actual. The target value may be a constant or it may be a polynomial that varies with steam flow to the HP turbine. The heat rate deviation can be read from a table or if the loss curve from the turbine manufacturer can be approximated as a straight line with a zero y intercept.

Throttle Pressure: -

Throttle pressure is the difference between the target and actual throttle pressure. This difference is proportional to the heat rate effect. If the steam pressure to the turbine is lower than design, the steam will not have as much pressure energy, which will require greater steam flow to produce the same amount of electricity, thereby raising the heat rate. This effect is calculated very similar to throttle temperature.

Hot Reheat Temperature:-

Hot Reheat Temperature is the difference between the target and actual hot reheat temperature. This difference is proportional to the heat rate effect. The hot reheat steam is the inlet steam source of the intermediate pressure (IP) turbine, in most power cycles. If this temperature is lower than design, the amount of energy entering the IP turbine is reduced, which then requires greater steam flow to produce the same amount of electricity, thereby increasing heat rate.

Reheat (RH) Pressure Drop:-

RH pressure drop effect is based on the difference between the target and actual steam pressure drop across the reheater value. If the actual RH steam pressure drop is greater than target there will be less available pressure energy in the steam to generate power in the IP turbine. This will require a greater amount of steam flow at the same load point which will increase the unit heat rate. This loss is calculated similarly to the throttle steam temperature.

RH Attemperation:-

RH attemperation flow represents water from the cycle that is sprayed on the steam entering the reheater to cool it when temperature control is necessary. However, the water that is used to cool the steam would have otherwise went to the boiler and ultimately be routed through the HP turbine to generate electricity. The RH attemperation flow gets subtracted from the cycle before the boiler and gets added downstream of the HP turbine. This equivalent amount of steam does not get a chance to generate any electricity in the HP turbine and causes an efficiency loss. The associated heat rate effect is proportional to the RH attemperation flow utilized and is calculated similarly to throttle temperature.

Condenser Performance:-

Condenser Performance is the efficiency loss due to the condenser back pressure being higher than the target value.

Target Back pressure-

The target back pressure is generally determined by a three dimensional curve that varies the back pressure with the steam flow or unit generation and the circulating water inlet temperature to the condenser. The amount of circulating water flow flowing through the condenser tubes affects both the target and actual back pressure. If the unit has multiple condenser circulating water pumps, a separate target back pressure curve will be necessary for the number of circulating water pumps in operation at that time. Once the target value is determined, it can be compared with the actual back pressure to calculate the difference. Figure 8 shows a typical curve. Note that the X-axis may be either generation or steam flow. The curve that the condenser manufacturer supplies is generally based on steam flow. The analysis process to obtain the target back pressure is similar to the heat rate deviation determination.

Condenser performance heat rate effect:-

There is another three dimensional curve that is supplied by the turbine manufacturer that is utilized to determine the heat rate effect. Both the target back pressure and the heat rate effect curves are generally at least 3rd order polynomial equations. Note that the heat rate effect is calculated as the difference between the target back pressure and the actual to eliminate the uncontrollable factors such as ambient conditions from the unit controllable effect.
To calculate this effect:

1. Fit the target back pressure to a polynomial (generally a 2nd to 3rd order polynomial). Note that there may be more than one target curve due to different configurations of circulating water pumps being in operation if the unit has that capability.

2. Fit the back pressure heat rate effect to a polynomial (generally a 3rd to 5th order polynomial). This curve is available from the turbine manufacturer or from the initial unit acceptance tests.

3. Calculate the fractional heat rate effect of the actual back pressure.

4. Calculate the fractional heat rate effect of the target back pressure.

5. Calculate the difference between the fractional heat rate effects of the actual and the target back pressure.

6. Multiply the fractional heat rate effect by the actual net unit heat rate to obtain the heat rate effect in Btu/KWh.

Feedwater Heater Performance:-

If high or low pressure feedwater heaters are out of service or operating off their design point, there is an associated heat rate effect. The total heat rate effect can be calculated by summing the effects of the heaters that are out of service and the heaters not operating at their design point.

A digital flag to indicate whether a feedwater heater is in service is helpful when performing these calculations. For example, a flag value of one could indicate the heater in is service and a value of zero could indicate it is out of service. One method of calculating this service flag is to calculate the feedwater temperature rise. If it is less than a minimum value, the heater can be considered out of service. If a service flag indicates a heater is out of service, PI Event Frames and PI notifications could be generated to track the event and inform the appropriate individuals. The out of service effect can be calculated using an energy balance modeling program to simulate the heat rate effect or it can be approximated using the rule of thumb.

For heaters that are in service, there are two important parameters in evaluating their performance. These are the terminal temperature difference (TTD) and the drain cooler approach temperature (DCA).
While in service the off-design effect is measured with the terminal temperature difference (TTD). The TTD is defined as the condensing (or saturation) temperature of the extraction steam minus the feedwater outlet temperature.

$$TTD = Extraction\ Steam\ Saturation\ Temperature - Feedwater\ Outlet\ Temp$$

This measures how close the water is heated to the condensing (or saturation) temperature of the extraction steam entering. For LP heaters, the TTD is generally about 3 to 5 ° F. For HP heaters, it is generally about -3 to 0°F. The design values are dependent on cycle configuration. The heat rate effect can be calculated using an energy balance modeling program or it can be estimated if that level of accuracy is acceptable. For a HP heater, an approximate heat rate effect could be about 1 Btu/KWh for each degree TTD is greater than design. This is dependent on configuration (i.e. for a dual, parallel heater strings the effect would be half). For an LP heater it is about 1/2 Btu/KWh. As with the HP heaters, if there are dual parallel strings, the effect is cut in half. The effects of all heaters are summed to calculate a total effect. Note that as mentioned previously, these values are dependent on cycle configuration and may vary.
The total heat rate effect is then calculated by summing the effects of any heaters being out of service and the ones operating off their design point.
One additional parameter that has less of an effect on heat rate but is useful to monitor for long term heater reliability is the (DCA). The DCA measures the amount of drain cooling zone sub-cooling. It is defined as: $DCA = Drain\ Outlet\ Temp - Feedwater\ Inlet\ Temp$
A typical DCA for an HP or LP heater that has a drain cooler is about 10 - 15°F. This implies that the drain temperature is being cooled to within 10°F of the feed water inlet temperature. As the DCA increases, the drain temperature increases which indicates a problem in the heater drain cooler. A common cause of a high DCA is a low heater liquid level. Operating at this level can cause long term damage to the heater drain cooler. Therefore, this is a useful parameter to monitor on line. See Reference 2 for more information.

Turbine Condition: -

The efficiency of the steam turbines will affect the heat rate if it is lower than target. In online monitoring, the calculated efficiency of the HP and IP turbines is compared to a target curve supplied by the manufacturer or from initial unit acceptance tests. Acceptance test data represents an actual historical performance measurement and is often the best comparison unless design modifications have been made to the turbine affecting efficiency. The amount of the difference between the target and actual efficiency is proportional to the calculated heat rate effect. The effects of the HP and IP turbines are summed to obtain the total turbine condition effect. Note that the LP turbine efficiency is not normally calculated in online performance monitoring because of the steam exit conditions being partially condensed (often termed "wet" steam). This requires additional energy balance calculations not normally performed in typical online monitoring.
The efficiency is calculated by the following:

$Turbine\ Efficiency = (h\text{si} - h\text{so}\ h\text{si} - h\text{soi}) \times 100$ **where:**

hsi = steam inlet enthalpy
hso = steam outlet enthalpy
hsoi = theoretical steam outlet enthalpy in an isentropic process (no entropy gain)

The efficiency of the HP and IP will degrade gradually due to wear between turbine overhauls. It is important to follow the starting and loading instructions to avoid any events that cause an operations or efficiency issue with the machine.
To calculate this effect:

- Obtain the equation of the target efficiency versus steam flow for the HP turbine. The IP turbine target efficiency typically does not change over the load range and the target efficiency is therefore represented as a constant.
- Subtract the difference between the target and actual values and multiply the result by the known heat rate effect of each percent turbine efficiency. If this value is not available, as mentioned in Reference 7, a useful fossil turbine rule of thumb is 0.16% heat rate per percent efficiency difference for both the HP and IP turbines.
- Add the two heat rate effects and then multiply by the actual new unit heat rate to obtain the heat rate effect.

Auxiliary Power: -

Using greater than the optimal required auxiliary power raises the net heat rate and cost of generation because it correlates to using power internally that reduces the net generation provided to the power grid. Many fossil generating units have increased auxiliary power usage since inception due to additional equipment added such as waste water treatment systems, added fan capacity, added mill capacity, pollution control systems etc. Reducing the amount of auxiliary power consumption requires constant monitoring and diligence. This effect could be reduced by running with the proper amount of equipment in service (I.E. condensate, boiler feed pumps and circulating water pumps, air compressors, etc.). Note that a 1 % of auxiliary power reduction is equivalent to a 1 % heat rate reduction. Therefore, this can be a very prominent effect on heat rate.

There are various pieces of equipment shared among the units. This equipment is commonly called station service equipment and its auxiliary power is allocated among the units in operation by their generation level.

Steam and water loss: -

The normal and emergency make-up water flows are added to obtain total make-up. From this the losses that can be accounted for are subtracted (I.E. soot blowing, aux steam, building heating, blowdown flow). The difference is steam and water loss flow. This flow is proportional to the heat rate effect. Note that this flow will vary with unit transients such as load changes. Makeup due to steam and water loss is often one of the largest controllable losses. Steam and water loss wastes energy that could have otherwise generated power. It is important to remember that the amount of energy required to change water to steam in the water walls is about twice the amount of energy added in the super heater and about three times the energy added in the reheater.

In theory the flow and the energy content of the steam or water leaking determine the amount of energy lost. In reality, there is no PI Tag to provide the exact location of the leak. Depending on where the leak is located in the cycle the enthalpy can be between 500 and 1500 Btu/lb. Therefore, in online monitoring, a reasonable approximation is to multiply the makeup flow by an assumed energy content (enthalpy) of 1000 Btu/lb to obtain the energy lost. This represents an average energy between the boiler inlet feed water and the steam outlet enthalpy. To calculate this effect:

- Multiply the net makeup flow by the assumed enthalpy to obtain the heat loss in Btu/hr
- Divide this value by the net generation to obtain the effect in Btu/KWh

Gas Outlet Temperature: -

The flue gas outlet temperature effect is calculated by subtracting the optimal air heater gas outlet temperature from the actual gas outlet temperature. Note that the air heater is the last opportunity that any useful heat transfer can be obtained from the flue gas going to the stack. After the air heater the gas flows through the precipitator or bag house, ID fans and up the stack and any excess energy is wasted. Therefore, it is important to maintain the air heater gas outlet temperature as close to optimal as possible to maintain the optimal boiler efficiency.

If the heat rate effect on the gas temperature is not available, a useful estimation is: every 50°F of gas outlet temperature above optimum is worth about 1% of boiler efficiency. A 1% boiler efficiency effect will equate to a 1% heat rate effect for the same unit generation. This linear relationship can be easily calculated in PI Asset Analytics:

1. Subtract the actual air heater gas outlet temperature from the target value and dividing the difference by 50. This value represents the percent heat rate effect of the excess temperature.
2. Divide this value by 100 and then multiply it by the net unit heat rate to obtain the controllable loss in Btu/KWh.

Conclusion: -

This document has discussed the importance of heat rate and controllable loss monitoring and has described how to calculate these parameters using the PI System. Online performance monitoring of the heat rate and controllable losses allows the Operations and Engineering teams to be made aware of any efficiency issues and make adjustments promptly instead of waiting until the end of the month when the typical reporting is performed. In order to point out issues promptly, PI Notifications and PI Event Frames can be utilized if a particular loss exceeds an established maximum trigger point.

The document has also described the important PI System Architecture components and how they can be assembled.

Chapter 5: Interpretation of Results

Case – 1 (18-01-2019)

Equipment: Unit-1 APH-A Motor (Support bearing temperature of APH-A motor)

Early warning since: 06:19 on 18-01-2019

APH-A tripped on: 01:15 on 19-01-2019

Part load operated till: 07:16 on 23-01-2019

Approx. stoppage time = 5.25 days

Considering 50% generation loss

Generation loss = 5.25*24*306.9*1000 kWh = 38.67 MUs

Cost implication = 38.67 MUs * Rs 1.29 = Rs 4.99 cr.

If the APH was stopped in planned way taking alarm in account, minimum one day required for resource planning & mobilization could have been saved

Potential Saving = 24*306.9*1000 kWh Mus * Rs 1.29 = Rs 0.95 cr.

Net Savings which could have been done = Rs 4.75 cr.

Case – 2 (22 July 2019): -

Equipment: Unit-2 ID Fan-B Vibration (Level & Vertical vibration ID fan B)

Early warning since: 22-07-2019 09:19

ID Fan-B tripped on: 22-07-2019 18:46

ID Fan-B restarted at: 22-07-2019 on 23:59

Approx.. stoppage time = 5.25 hrs.

Considering 50% generation loss

Generation loss = 5.25*306.9*1000 kWh

=1.612 MUs

Cost implication = 1.612 MUs * Rs 1.29

= Rs 20.78 lacs

Net Savings which could have been done

= Rs 20.78 lacs

Case – 3 Date: 18 Oct 2019

Equipment: Unit-1 PA Fan-B Process

Early warning since: Alarms visualized on 03-10-2019 09:43 and remain active till 12.55. Then alarm became active again on 17-10-2019 19:40 and remain active till 18-10-2019 21:04.

Early warning on: Blade pitch position

PA Fan-B stopped on: 18-10-2019 21:06

Case -4 Shutdown taken for Fan at – 21:06 on 18-10-2019

Fan restarted at – 01:10 on 19-10-2019

Aprrox. stoppage time = 4 hrs

Considering unit may've tripped on PA Header pressure low in case S/D not taken

Generation loss = 4*613.8*1000 kWh = 2.455 MUs

Cost implication = 2.455 MUs * Rs 1.29 = Rs 31.67 lacs

Best achieved oil consumption in any hot start-up = 25 kL

Cost of oil consumption = 25 kL * Rs 48,000 = Rs 12 lacs

Total Saving – Rs 31.67 lacs+ Rs 12 lacs = Rs 43.67 Lacs

Note – For calculating payback it has been assumed that unit would have been restored in same time as taken in the planned S/D. Oil consumption has been taken as best achieved.

Chapter 6: Conclusions and Scope for Future Work

What we have done till now.

1. Auto reports triggering

We've configured as many as 21 reports out of which three reports are shift-wise and twelve reports are day-wise. Some of the important reports generated are BMT Excursion report, Critical parameter deviation, ABT export report, Controllable losses report and many others. The auto-report generation has significantly minimized human interventions and directed human resources in doing other productive works. Also auto-reports generated have reduced human error and increased the accuracy of data. Earlier compilation of report was done and then mailed by copying from one system to other using CD-Drives.

2. Accessing data from remote location

We can now access or visualize data and process parameter from a remote location in our laptops, tabs or phones. This doesn't put a boundary to be in Vedanta network, that means we can do the same using our personal internet data. This has increased the data monitoring even if you're not in the office or plant. Now we don't need to call the desk operator to know what is the value of MS pressure or MS temp or to know what is the current heat rate deviation due to use of make-up water. Every important KPIs have been put on a central platform which can be monitored in real-time.

3. Centralization of Data

Earlier the main plant (i.e. BTG) was controlled by DCS and other areas like CHP, AHP, DM plant (i.e. BOP) by PLC. So there was no centralized platform to view overall plant performance on a central platform, but with this project we've build configured data coming from various areas to a common place. Using this we've build dashboards through which we can monitor data coming from either BTG or BOP. We can now monitor the ESP field DP and Coal flow simultaneously on a same page.

4. Event-based & Time-based alert notifications on Phone

Alarms are popped up in DCS but that is only known to the desk operator or to the shift-in charge. But in this case alarms can be directly seen in our phone in form of a telegram message or as an E-Mail. This will escalate any deviation from maximum allowable limits for process parameter.

Also now we can get hourly-updated of parameters like unit load, coal flow, ESP field & silo level. This will keep the concerned person updated about trend of load, coal flow and other parameter.

5. Fleet Monitoring (Early warning system)

We've incorporated Fleet Monitoring software in our Model server for early anomalies detection. Based on this we can predict the breakdown of certain equipment and that particular equipment can be taken into maintenance planning. This will reduce the unplanned outages of equipment. Currently there is an FM report generated daily which shows the alarms in different state-estimator (commonly known as model). Against this, an analysis is done by Operation team whose work is to allot the alarms to different maintenance departments. Also the models require periodic fine tuning for continuous improvement.

Scope of Future Work (What we are planning to do): -

1. ESCADA integration with PI system through DCS for real time APC monitoring. This will enhance monitoring of aux power of equipment which draws more power relatively.
2. SAP – S/4 Hana Integration. We can directly use PI Integrator tool for easy integration of SAP S/4 Hana with PI system. This will reduce the effort of manually updating of certain parameters like coal consumptions for the day. We can also track the downtime of various equipment.
3. E-shift log can be prepared for every shift reducing the effort operator and it was also help in maintaining a central database for shift logs.

Bibliography: -

- Discussion with guide.
- Discussion with colleuge.
- Take online support from google search engine.
- Book available from plant library.

References: -

- Power Plant Parameters