

Hazard and Operability study in Boiler System of The Steam Power Plant

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Abstract. The Pulverize is a major part of the boiler combustion system and an important part in the system of steam power plant (PLTU). Pulverizer plant serves to break chunks of coal into the coal ash was then fed to the burner. Type of feed coal into a pulverize is cleaned with a value product pulverize optimum 30%. The percentage of this value greatly affects the production of steam in the boiler. Therefore the boiler has a very high pressure, is inflammable zone and has a dangerous and potentially very high risk, and then the system needs to be investigated. By performing an evaluation and analysis of critical points in the pulverize, boiler, measuring the level of danger and risk that occurs, and examine other possibilities that would occur in the worst condition by using hazard and Operability (HAZOP) studies by recording the deviation values variable process, making the model Fault Tree Analysis (FTA) and to simulate, it can be known the level of hazard and risk systems, so you can make recommendations and created a new work instructions..

Key-Words: *Pulverizer, Boiler, Steam power plant, HAZOP, Fault Tree Analysis.*

1. Introduction

The Boiler is an important component of the system of steam power generation (power plant) Unit 7 PT. IPMOMI Paiton-Probolinggo. Boilers can be divided into three systems of feed water system, steam system and fuel system. The third integrated system so that if small changes will affect the quality of the resulting vapours temperature and pressure. Boiler fuel system is one system that serves the combustion process. This system is most at risk as the cause of the explosion and fire. Safety system must be considered in order to keep the system functioning properly. The main components of the combustion system are functioning Pulverize coal breaking into coal ash then fed to the burner. The total feed coal which fed optimum value worth 30% cleaned pulverizes of the resulting product. This situation greatly affects the quantity of boiler production. By this system has high pressure and is then flammable zone potentially harmful.

By applying the method of Hazard and Operability (HAZOP) Study on the system that includes evaluation and analysis to include identification of critical points in the activity pulverize process and identification of the source parameters of both the dangers associated with system design and process activities and perform analysis on various parameters and simulate then the system can be made an assessment of whether or not an action taken to hazards control. The next procedure is made based on the existing deviations in the process and made recommendation to the possibilities that will happen. The accusation data was made during normal working system. The process-variable input and output process include temperature, flow rate and pressure in sampling. Analysis carried out on 13 points by using data acquired during 1 month (October 10, 2008 00:00:00 to November 11, 2008 00:00:00) with a sampling interval of once every 4 hours. Software used to analyze the deviation is MINITAB Release 14. The design of simulation software HAZOP using Lab VIEW 8.2.1. Cause and consequence analysis performed by the method of fault tree analysis (FTA) and the guide-word [1].

2. Plant and System

Pulverize is part of the boiler combustion system that functions to process coal into coal ash, further on the fed directly as a fuel furnaces. Pulverize studied is type ABB-CE Series Pulverize or "Deep Bowl mill" shown Figure 1. Pulverize divided into several sections, among others: coal feed inlet as a rough entry into the coal pulverize comes first in the capacity of coal in coal silo. Separator to separate fine coal and coal that still needs to be processed further and the coal that was not applicable. Air inlet as the air supply, air pulverize requiring fixed temperature for the process, so before entering the air through the pulverize in primary heating water heater up to a certain temperature. Pulverize has three main parts include, Pulverize capacity, this capacity is influenced by several things such as the initial capacity pulverize, grind ability Hardgrave Index (HGI), corrections, corrections and size moistures corrections. Formulation capacity = (rated capacity) (HGI correction) (correction moistures) (size correction). Pulverize air (PA) or fuel ratio, this section is a very critical part of the pulverize for change and a significant failure would be devastating to the whole process. PA flow performance improvement can be done with improvements to the connection, reducing corrosion components, reducing the primary air fan capacity, reducing existing barriers testing water clan and improve

pulverize performance. Pulverize are the most important part of the control on air flow and temperature. Fuel flow curve relationship and primary air flow is shown in Figure 2. [1-2].

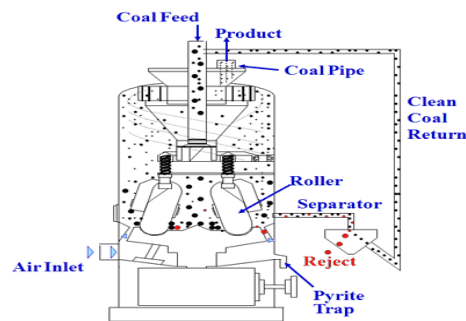


Figure 1. Pulverizer system

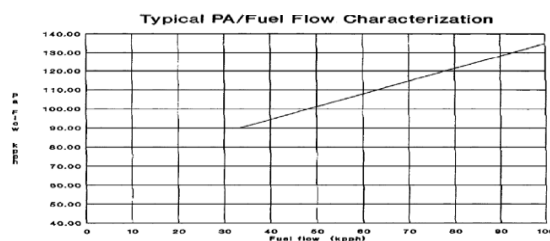


Figure 2. The relationship of fuel flow and air flow on the pulverize

HAZOP is a standard technique for the danger analysis to preparation the security setting on the new system or existing to measure the presence of potential dangers. HAZOP purpose is to review a process or operating system systematically, to determine deviations from the potential dangers. HAZOP is studying the possibility of deviation from normal operation. HAZOP has a systematic character structure or have a high level structure that relies on guide words. HAZOP can be applied to various systems and application procedures, which is emphasized as an interpreter of the dangers and techniques as early predictor, so as to produce good quality. HAZOP can be used together in safety hazard identification process, the operating system is continuous and jointly review the procedures used to set the operating system.

Operability or condition that are considered dangerous and analyzed with the HAZOP are: Fire and explosion, damage to facilities and equipment, safety and health hazards to personnel, emergency shutdown systems (ESD), Operability or Maintainability problems, plant non-availability, environmental impacts, construction and commissioning hazards. HAZOP Study Before starting takes some initial information such as covering preliminary HAZOP; Process flow sheet/process flow diagram (PFD or PFS) and discription of the process. The details include HAZOP; piping and instrumentation diagrams (P&ID), process calculation, process data sheets (heat and material balances), instrument data sheets, Interlock schedules, layout requirements, hazardous area classification, schedule of alarm trip setting, cause and effect chart , specifications piping materials, piping layout and play an elevation drawings and electrical diagrams single line. After all the necessary information is met, HAZOP procedure can be performed with the following stages: The division of the system into several parts based on the most important component of the process. The selection stage study (such as line, vessel, pump, operating instruction, etc.). Describe the purpose of the design (iintent design), select the process parameters, apply the guide-words, identify the causes that exist, evaluate the problems that arise and define the possibilities and potential dangers of giving either frecommendation action safety measures or systems. The model HAZOP consists of; Diagraph Model HAZOP, HAZOP in this analysis of cause and consequence of drawing a diagram in the form of interconnected between one consequences with others. HAZOP and iinterlock system integrity aanalysis, in this HAZOP cause and drawn consequence with tables that can be seen in the integration of HAZOP and fault tree analysis models using (FTA) [2-3].

Formulate the value of UCL, LCL, standard deviation, and mean with the following formula:

$$\text{Mean /Center line (p)} = \frac{\sum X_i}{\sum n_i} \quad (1)$$

$$\text{Standard Deviation (k)} = \sqrt{\frac{\sum (x - \bar{x})^2}{(n-1)}} \quad (2)$$

$$\text{Lower Control Limit (LCL)} = p - k \sqrt{\frac{p(1-p)}{n_i}} \quad (3)$$

$$\text{Lower Control Limit (LCL)} = p + k \sqrt{\frac{p(1-p)}{n_i}} \quad (4)$$

3. Hazop Study and Process

HAZOP Preliminary is early stages of the process HAZOP study. At this stage of data acquisition performed. The process flow sheet/process flow diagram (PFD) and Piping & instrument diagrams (P & ID) which is the description of the process and components pulverize 7B. Generally contain; Interlock schedule is a logic diagram of the safety system on; layout requirements that describe the conditions in each of the main part of the system. Data acquisition process be done online at the DCS system; process data sheet (heat and material balance); hazardous area classification seen in manual book of pulverize 7B a pulverize inerting and fire fighting systems and operating procedures pulverize. Online of data taken at each sensor pulverize 7B, both Input and output variables including temperatures, flow rate and pressure. The next set of nodes which are analyzed points influential and has a high hazard level. A number of 20 points taken, there were 13 points that need to be analyzed and represents the entire process pulverize.

Data obtained from measurements 13 nodes, then each point to analyze by comparison of initial design data systems. Next deviation calculated value. To compare the two data MINITAB 14 used software, the software can be seen the results of statistical calculations, such as mean, standard deviation, Upper Control Limit (UCL) and Lower Control Limit (LCL). The measurements shown in the graph as show in Figure 3. Data processing is done by comparing the measurement data with design data, results comparison Xbar-R chart can be seen in Figure 4. From Xbar-R chart can be known types of deviation and the deviation value. Can be seen also how much data above Upper Control Limit (UCL) and the frequency and how the possibility of deviation that appears on the state of flow more [4-5].

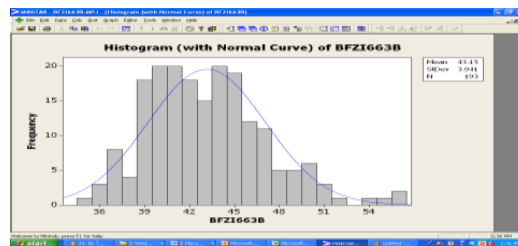


Figure 3. The measurement histogram

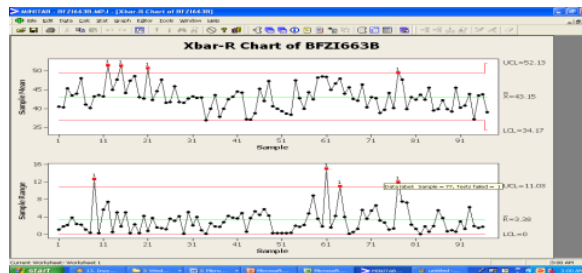


Figure 4. Correlation of Xbar-R chart

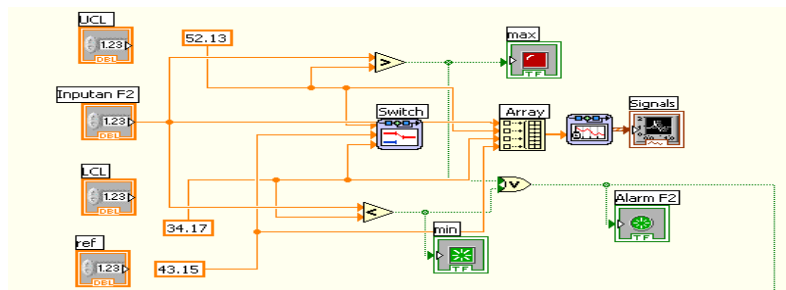


Figure 5. LabVIEW 8.2.1 program

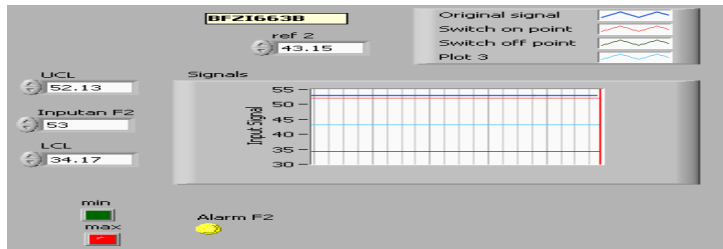


Figure 6. Simulation using LabVIEW 8.2.1

At this stage made the determination that its use guideword use based on the results of previous calculations, guide-word type used is based on the deviation parameter. Identify All Cause and Record, After the deviation is known, conducted an analysis of causation. List of possible cause's guideword and used to see the cause of the deviation. Review; P&ID, Interlock and manual book schedule in Table 3. Identify All Consequence and Record ; At this stage to identify consequence that results from deviation. Also looking for a one-junction with another junction. Further simplified interconnection deviation and analyzed using Fault Tree Analysis (FTA). Agree any Action Necessary and Records; the identification fase of cause and consequence followed by a simulation in the form of simulation software HAZOP with Labview 8.2. Here are examples of programs and simulation Figure 5-6. [5].

Table 1. Correlation of guide-word and process parametre

Guideword	Parameter					
	Flow	Presure	Level	Temperatur	Viscosity	Contaminan
No	X					
Less	X	X	X	X	X	
More	X	X	X	X	X	
Part of						
As well as						X
Reverse	X					X
Other than						X

Table 2. Aplication of guide-word

Guide-word	Meaning	Example
No(not,none)	None of the design intent is achieved	No flow when production expected
More (more of, higher)	Quantitative increase in a parameter	Higher temperature than designed
Less (lessof,lower)	Quantitative decrease in a parameter	Lower pressure than normal
As well as (more than)	An additional activity occurs	Other valves closed at the same time (logic foul of human error)
Part of	Only some of the design intention is achieved	Only part of the system is shut down
Reverse	Logical opposite of the design intention occurs	Back-flow when the system shuts down
Other than (other)	Competete substitution-another activity takes place	Liquids in the gass piping

Table 3. Guide-words include causes

GUIDEWORDS	POSSIBLE CAUSES
NO FLOW	Wrong routing-blockage-incorrect slip plate-incorrectly check valve-burst pipe-large leak-equipment failure(C.V.,isolation valve,pump,vessel,etc.)-incorrect presure differential-isolation in error.
LESS FLOW	Line restrictions-filter blockage-defective pumps-fouling of vessels, valves, orifice plates – density of viscosity changes.
REVERSE FLOW	Defective cheks valve- siphon effect – incorrect pressure differential – two way flow –emergency venting-incorrect operation-in-line spare equipment.
MORE FLOW	Increased pumping capacity- increased suction presure- reduced delivery head-greater fluid density-exchanger tube leaks-restriction orifice plates deleted-cross connection of systems-control faults-

	control valve trim changed-running two pump.
MORE LEVEL	Outlet isolated or blocked-inflow greater than outflow-control failure-faulty level measurement – gravity liquid balancing.
LESS LEVEL	Inlet flow stops – leak – outflow greater than outflow – control failure –faulty level measurement – draining of vessel.
MORE TEMPERATURE	Ambient conditions-fouled or failed exchanger tubes – fire situation – cooling water failure-defective control – heater control failure-internal fires-reaction control failures-heating medium leak into process.
LESS TEMPERATURE	Ambient conditions-reducing pressure-fouled or failed exchanger tubes-loss of heating-depressurerisation of liquefied gas-Joule/Thompson effect.
MORE PRESSURE	Surge problems-connection to high pressure system-gas breakthrough (inadequate venting)-defective isolation procedures for relief valves-thermal overpressure-positive displacement pumps – failed open P.C.V.'s –design pressures, specifications of pipes, vessels, fittings, instruments.
LESS PRESSURE	Generation of vacuum condition – condensation – gas dissolving in liquid – restricted pump/compressor suction line – undetected leakage – vessel drainage-blockage of blanket gas reduction valve.

4. Discussion and Analysis

At this stage of data processing are discussed, the calculation of the deviation, fault tree analysis, simulation and analysis system. Analysis of each node and determining deviation, Analysis performed on 13 points from the pulverize system, with the parameters measured flow, pressure, and Temperature. The image of each node can be explained in more detail. Because the number of nodes are analyzed so much, it can be exemplified here with two nodes for the analysis. The next of performed each point. Node1 primary air heater outlet pressure (BFPI660B); this section is the beginning of the input into the pulverize system. Here in the pressure magnitude measured at initial input, i.e. the primary hot water which is the output of the primary water heater. Sensor shown in Figure 7.

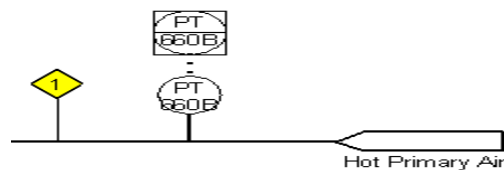


Figure 7. The sensing of hot primary air - BFPI660B

Calculations obtained with the software as follows:

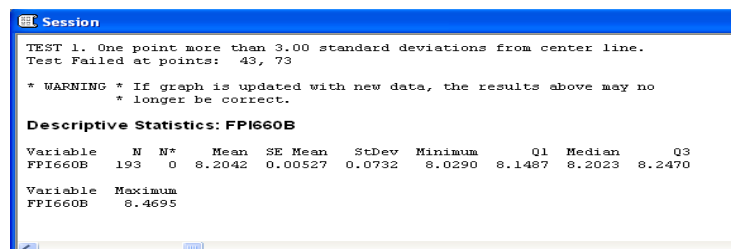


Figure 8. The results of the calculation of BFPI660B

Graphically shown by the following histogram;

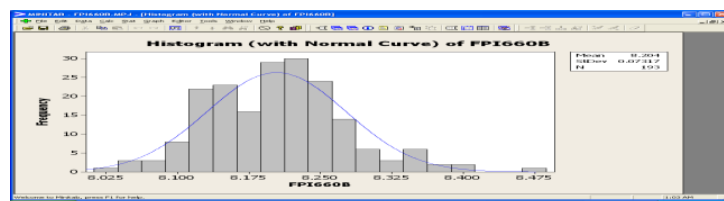


Figure 9. Histogram of BFPI660B

Analysis Xbar-R model to determine the deviation that occurs, as follows:

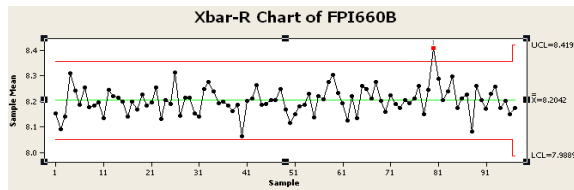


Figure 10. Xbar-R Chart from BFPI660B

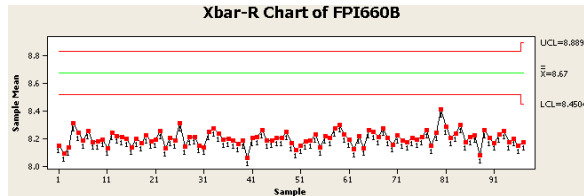


Figure 11. Comparison of Xbar-R Chart BFPI660B

The calculation step shows Figure 7-11. , the value of UCL = 8.4195 Kpa, centre line = 8.2042 Kpa and LCL = 7.9889 Kpa, when centre line is BFPI660B initial design, the value = 8.67 Kpa, which generated Xbar-R chart is different. From the comparison can be seen, all data is located below the design value. With a mean value = 8.2042 Kpa which was far below the value of the specified design pressure = 8.67 Kpa, thus the deviation component is BFPI600B less pressure.

4.1. Node2.Hot Air Damper Position (BFZI663B)

Hot air damper position is a second sensor in the primary hot water line. Sensors measured parameter is the flow rate of the primary hot water. Change hot water damper (BFZI663B) greatly affect the temperature and flow rate pulverize 7B. In hot water are components of damper position hot water shutoff gate that serves as a hot shutdown of water flow system flow, such as show Figure 12. [6-7].

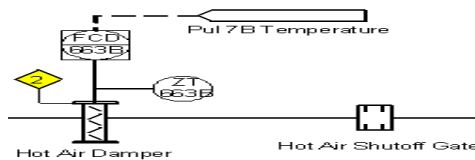


Figure 12. Hot water damper - BFZI663B

Statistical calculations with formulations 1-4. As Figure 13.

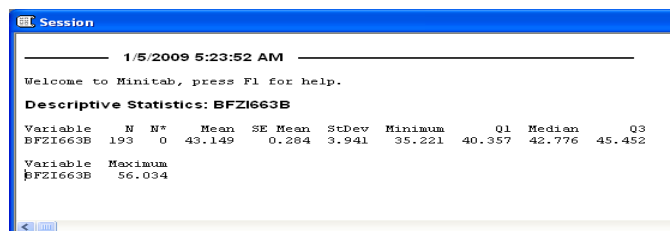


Figure 13. Statistic calculating of BFZI663B

To calculate the value of UCL, LCL, standard deviation, and mean with the following formula;

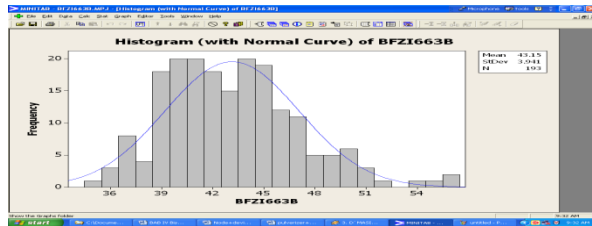


Figure 14. Histogram of BFZI663B

Model of Xbar-R for calculation deviation shown in Figure 15.

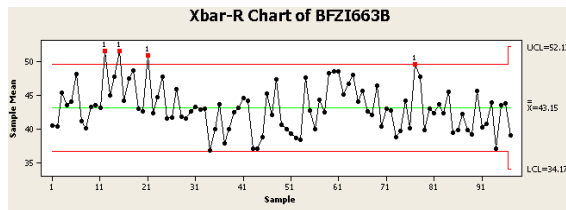


Figure 15. Xbar-R Chart from BFZI663B

Figure 15. Indicates that the value of $UCL = 52.13\%$, $43.15\% =$ Center line and $LCL = 34.17\%$, a trend seen from the graph of measurement results in the center line. In the graph there are four points above the UCL deviation, which is a sub group 12, 15, 21, and 77. So that the deviation is BFZI663B more flow.

4.2. The identification of causation (Identify Cause and Consequence)

Final stages of implementation, HAZOP study is to identify, prior to simulation and analysis; Identify Cause, Identification cause of the deviation is based on a study of P & ID, Interlock Schedule, and the manual book (Pulverize inverting, Fire Fighting System and Operating Procedure Pulverize). Identify Consequence, identification is based on the analysis due to deviation of each node and find a relationship between a deviations that resulted in another deviation. To connect an effect on other components used Fault Tree Analysis method (FTA). Here's FTA modeling shown in Figure 16.

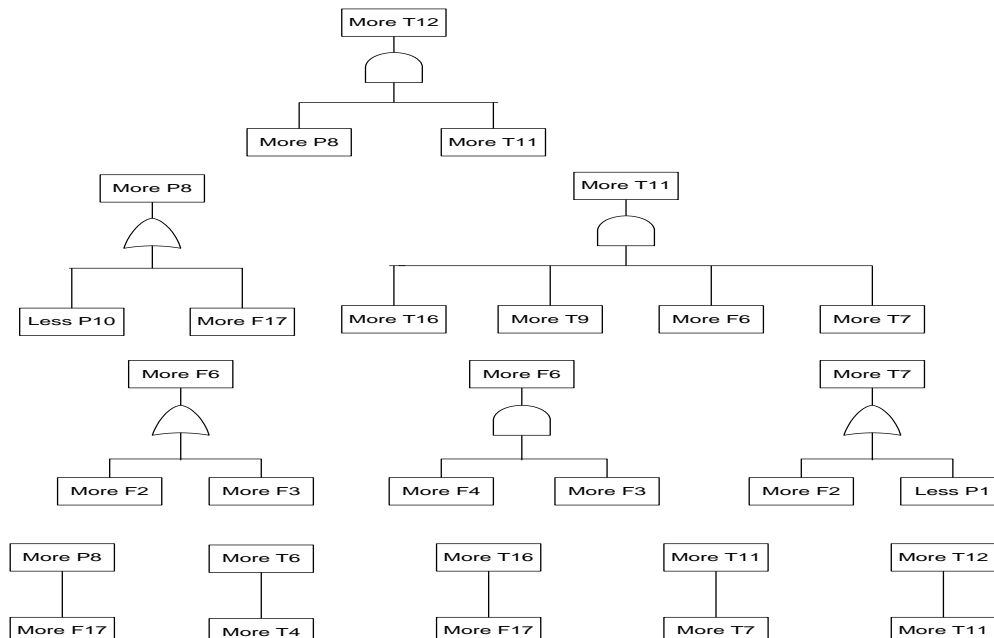


Figure 16. Model system using FTA

4.3. Simulation

Simulation is done on one node system with programming phase fault tree analysis is made, the identification of hazards, calculate the deviation, is then performed simulations, as in Figure 17. From the calculation, $UCL = 52.13$, $LCL = 34.17$. Reference node 2 is the initial design. If the input value is greater UCL, then the alarm occurs, the red light will illuminate to indicate the maximum flow rate F2 followed by alarm sensor turns on. Conversely, if the entered value is smaller LCL, the alarm light green, which indicates the minimum flow rate, alarm sensor will turn on F2 indicates a deviation. If the input value in the stable (between UCL and LCL), the third alarm was not on. Any changes to the system can be monitored through a graphical simulation. Shown in Figure 18.

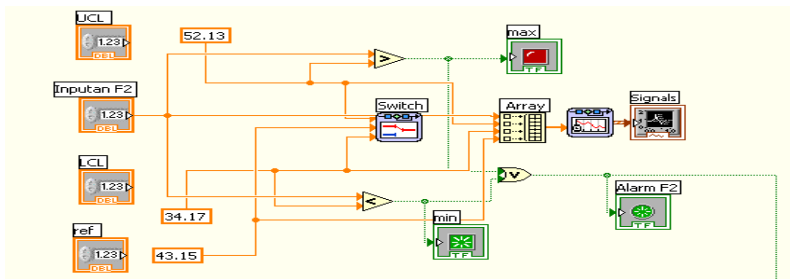


Figure 17. Program LabView untuk Node 2

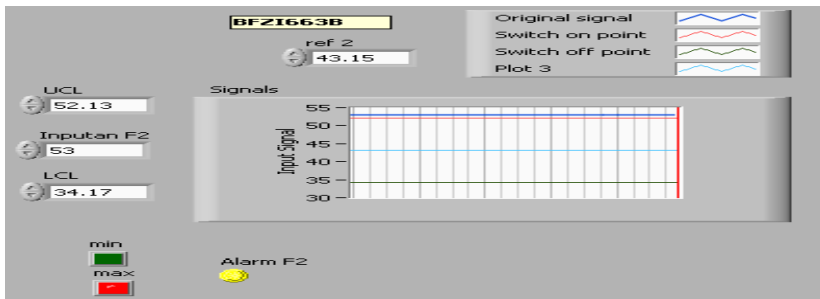


Figure 18. Simulation for Node 2

Simulation for Some Node FTA, Simulation of a node with FTA on node 1, node 2 and node 7, show Figure 19.

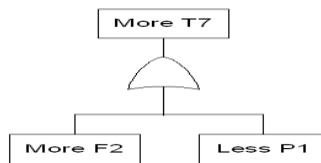


Figure 19. FTA for Node 1,2,7

Development of FTA followed by creating a program in LabView as Figure 20.

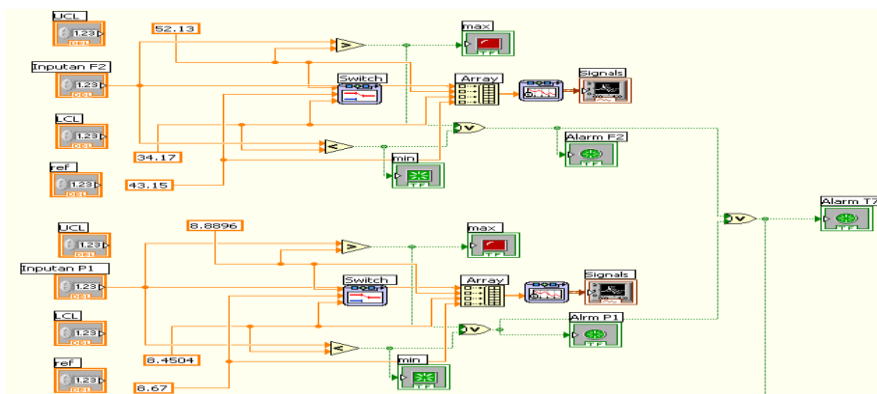


Figure 20. Program LabView untuk FTA

By using the logical "OR" in the event of deviation on one node, both node 1 and node 2, it will cause deviation of the node 7. indicated by "Alarm T7". On programming the display in Figure 21.

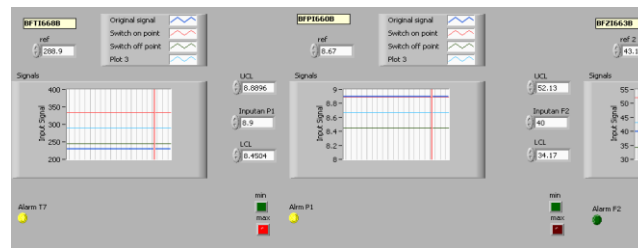


Figure 21. Simulation for FTA

Table 4. Identification Cause and recommendation

No de	Component	Deviati on	Possible Cause	Recommendation
1	Primary Air Heater Outlet Pressure (BFPI660B)	Less Pressure	Reducer hot air flow from Primary air Heater Plugged Pressure Tap/leak	<ul style="list-style-type: none"> - Check purge air and clean pressure taps as required - Check Primary air heater Operation - Check Air flow Control system
2	Hot Air Damper Position (BFZI663B)	More Flow	High Flow From primary Air Heater High Flow in cold air damper Low temperature from temperature control pulverize, oculet thermocouple malfunction.	<ul style="list-style-type: none"> - Check Primary air heater Operation - Check cold damper Operation - Check temperature control pulverize - Check thermocouple in Output pulverize.
3	Cold Air Damper Position (BFZI665B)	More Flow	High flow from primary air system High Flow in hot air damper High Temperature in primary air inlet temperature sensor Outlet thermocouple malfunction	<ul style="list-style-type: none"> - Check Primary air Operation - Check Hot damper Operation - Check temperature PA inlet mill - Check thermocouple in PA inlet mill
4	Primary Air Flow Transmitter B (BFFI667B-TPH)	More Flow	Excessive Cold Air Damper too High (Malfunction) Excessive Hot Air Damper too low High Differential Pressure PA Fans Inlet Cold Air Damper	<ul style="list-style-type: none"> - Check Cold Air Damper - Check PA Fans Inlet Cold Air Damper
6	Mill Air Flow (BFFI666B)	More Flow	Excessive Cold Air Damper too High (Malfunction) Excessive Hot Air Damper too low High Differential Pressure PA Fans Inlet Cold Air Damper	<ul style="list-style-type: none"> - Check Cold Air Damper - Check PA Fans Inlet Cold Air Damper
7	Primary Air Inlet Temperature (BFTI668/9B)	More Temperature	Excessive Hot Air Damper too High High Differential Pressure PA Fans Inlet Hot Air Damper Outlet thermocouple malfunction More Temperature from Pulveriser	<ul style="list-style-type: none"> - Check Hot Air Damper - Check PA Fans Inlet Hot Air Damper - Check Thermocouple
8	Pullover Bowl Different Pressure (BFPDI590B)	More Pressure	Over loaded pulverize Plugged pulverize pressure tap Excessive mill air flow Insufficient open area around the bowl	<ul style="list-style-type: none"> - Reduce feed rate to pulverize check feeder calibration, check coal grind ability - Adjust classifier blades (open) - Check purge air and clean - Check airflow control system
9	Motor Front Bearing Temperature (BFTI571B)	More Temperature	Bearing failure Low air level Oil cooler malfunction ,oil supply temperature high no oil flow	<ul style="list-style-type: none"> - Check for notice and inspect immediately - Check level and add oil - Check cooling water temperature and flow - Assure that oil pump is operating
10	Pull to Furnace Different Pressure (BFPDI589B)	Less Pressure	Reduce coal flow to mill Plugged pressure tap/leak Low mill air flow	<ul style="list-style-type: none"> - Check feeder operation and/or plug gage - Check purge air and clean pressure taps as required - Check air flow control system
11	Temperature Control Pull (BFTIC586B)	More Temperature	Pulveriser fire Hot air damper malfunction Cold air damper malfunction	<ul style="list-style-type: none"> - See fire fighting procedures - Cloche hot air gate, shut down mill, repair as required

			Feeder malfunction/ feed pipe plugged Outlet thermocouple malfunction	- Open could air damper manually, shutdown mill, repair as required - Verify readings and repair/replace as required
12	Boiler Corner 1 Temperature (BFTI550B)	More Temperature	Pulveriser fire Hot air damper malfunction Cold air damper malfunction Feeder malfunction/ feed pipe plugged Outlet thermocouple malfunction	- See fire fighting procedures, Cloche hot air gate, shut down mill, repair as required, Open could air damper manually, shutdown mill, repair as required, Verify readings and repair/replace as required
16	Feeder Outlet Temperature (BFTI561B)	Less Temperature	Extremely wet coal from Coal silo Less Flow From Silo Less Temperature from Silo Outlet Thermocouple malfunction	- Check Water Obstetrical From Silo - Check control flow from silo - Check temperature from silo -Verify readings and repair/replace as required
17	Feeder Coal Flow- BFF1500B	Less Flow	Less Flow From Silo	Check control flow from silo

5. Conclusion

Pulverize-known that the boiler is to have a high enough danger-level Can be seen from the analysis are that the junction temperature at high values PULVERIZER (T11) and pressure deviation is also high (P8). This situation resulted in increased temperatures of coal ash into the furnace temperature is higher (T12). Hazard Potential of Fault Tree Analysis drawn and simulated using LabView 8.2.1. Comprehensive results can be monitored for changes in the process based on changes in input. Through HAZOP Study recommendation system improvements can be made through the creation of work instructions, in addition to the identifiable causes of hazard, as shown in Table 4.

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