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Automated Control System Design for Ultra Supercritical Thermal Power

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ABSTRACT

The work taken up for this paper is the implementation of process automation using DCS for Ultra Supercritical thermal power plant. Coal has been the king in the global electric power production and will continue to serve in this role in the future. Worldwide energy and electricity consumption is projected to grow at an average annual rate of 2-2.5% between now and 2025 caused by increase of population (up to 7.5 billion) and increase of consumption (mainly of China and India).Hence, by increasing the efficiency of existing power plants, using clean technologies and adoption of ultra-supercritical boiler, wherever cost effective and otherwise suitable is preferred. The Gross plant efficiency is around 41-42% for ultra-supercritical units with steam parameters of 28MPa/975k, which is about 3-4% higher than that of the supercritical units. The control of large scale ultra-super critical power plant is very complicated and highly nonlinear because it involves the measurement and control of number of parameters in order to increase the overall plant efficiency by Optimizing the combustion process, increasing the steam parameters, reducing the condenser pressure and improving the internal efficiency of the steam turbines. Thus, Monitoring and control system such as DCS/SCADA are responsible for managing critical infrastructures operating in these environment. The control of various components such as once through boiler parts super heater (temperature, pressure, flow), reheater (temperature, pressure, flow), economizer (temperature, pressure and flow), air Preheater (temperature), burners (air/fuel ratio) and turbine operating conditions is implemented using the CENTUM CS 3000 of Yokogawa India ltd.

Keywords - Automation, coal fired power plant, control system design, Distributed control system (DCS), once through boiler, ultra super critical power plant.

1. INTRODUCTION

Ultra supercritical (USC) power plant is the next generation power plant which operates with a steam pressure in the range of 300 bar and steam temperature above 975k. The efficiency of the power plant is proportional to operating temperature and pressure which are limited by number of power plant components. In this thesis, the main objective is to to increase the efficiency of the power plant by Controlling and monitoring the pressure, temperature and flow through the once through boiler parts (super heaters, reheaters, economizers), air preheater, the temperature of HP,IP and LP turbine and also to maintain the air-fuel ratio of burner and furnace pressure. Various control system loops are implemented and graphic window for the USC power plant is configured.

2. 1000MW USC POWER PLANT

The power plant under investigation is a coal-pulverised, once-through-type, boiler-turbine-generator unit. The USC coal fired power plant consists of four processes, which are air/flue gas, pulveriser, water/steam, and turbine/generator.There are three economizers used to raise the temperature of water entering the boiler from the feed water system. Two forced draft fans and two primary air fans provide air to the air preheated. The air preheater in turn provides heated air to the pulverisers, burners, and furnace. The primary air fans also provide cold air to the pulverisers. The fuel is provided to the furnace through the pulverisers and burners.

Furnace pressure is maintained at the desired value by controlling two induced draft fans. The waterwall surrounds the furnace vertically and spirally. Flue gas exiting the furnace travels through the super heaters and reheaters, economizers, and air preheater to raise the temperature of the steam, water, or air, respectively. There is a separator on top of the furnace, which supplies high-pressure (HP) steam to the primary superheater and reduces the impurities in the steam.

The superheater consists of four parts: primary, division, platen, and finish. The reheater reheats the steam after the HP turbine using the primary reheater and the reheater finish. Finally, the turbine converts the enthalpy of the steam into rotary motion of the tandem compound triple turbines, which consist of three parts: a HP turbine, an intermediate-pressure (IP) turbine, and low-pressure (LP) turbine which is then connected to the alternator to produce electricity.

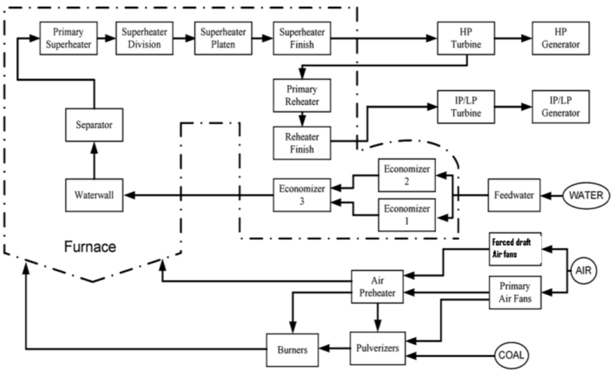

Fig 1. Block diagram of USC power plant

3. OPERATION OF DIFFERENT SUB SYSTEM

3.1 Air Preheater

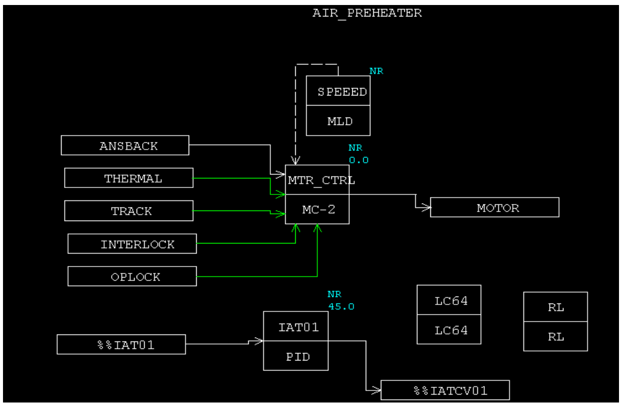

Fig.2. Control drawing builder of Air preheater.

The purpose of the air preheater is to recover the heat from the boiler flue gas which increases the thermal efficiency of the boiler by reducing the useful heat lost in the flue gas. Air of the temperature range 150-420 C is needed for drying coal in the pulveriser. The most common type is rotary air preheater known as Ljungstrom air preheater which consists of a rotor, driven by a motor. They are compact heat exchanger with large heat transfer surface and can be accommodated in small volume. As motor starts, metal plates move from hot combustion passage and exchange the heat to the cool incoming air.

3.2 Primary and Secondary Air Fans

A fan can be considered as a mechanical device that moves a volume of fluid such as air, gas or vapour through a pressure driven flow. The term draft indicates the movement of the combustion air and flue gases. Forced draft fan is used to regulate the combustion air. Induced draft fan is used to regulate the furnace pressure. Control can be done by fan speed or damper action. Furnace pressure is affected by both forced draft fan and induced draft fan.

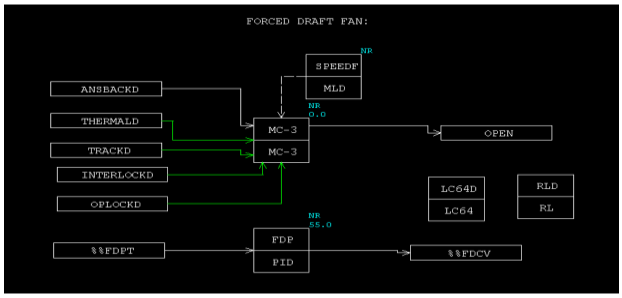

Fig.3. Control drawing builder of forced draft fan.

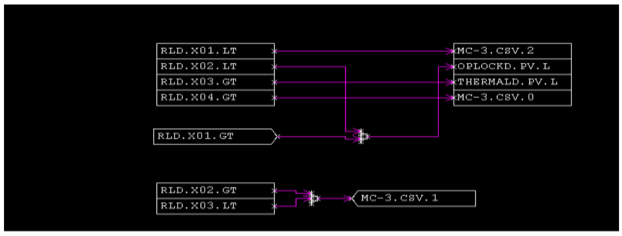

Fig.4. LC64 interlock for motor control.

3.3 Burner

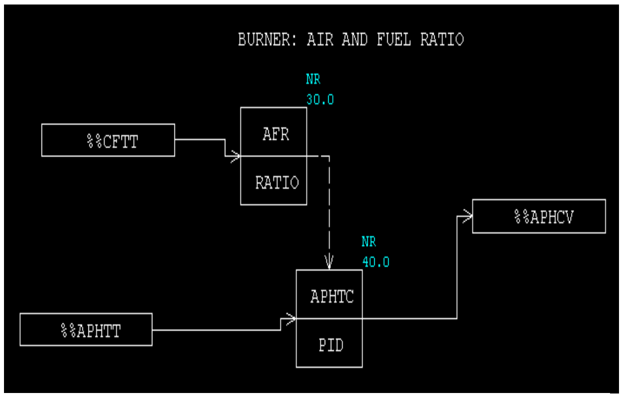

Fig.5. Control drawing builder of Air/fuel ratio

The raw coal is fed into the pulverizer along with air heated to about 650 degrees F from the boiler. Air–fuel ratio is the ratio between the mass of air and the mass of fuel in the fuel–air mix at any given moment. The mass is the mass of all constituents that compose the fuel and air, whether combustible or not.

4. ONCE THROUGH BOILER PARTS

Superheater is a heat exchanger in which heat is transferred to the saturated steam to increase its temperature. Steam temperature is normally controlled by spraying water into the steam between the first and second-stage superheater to cool it down. Water injection is done in a device called an attemperator or desuperheater. The spray water comes from the pump discharge (for superheater spray). Improved disturbance rejection can be achieved by implementing a secondary (inner) control loop at the desuperheater. This loop measures the desuperheater outlet temperature and manipulates the control valve position to match the desuperheater outlet temperature to its set point coming from the main steam temperature controller. In this case,3 desuperheater are present then FOUT block (CS3000) is used to distribute the signal from primary controller to 3 secondary controllers. OUT is a signal distributer block which has single master and multiple slaves..

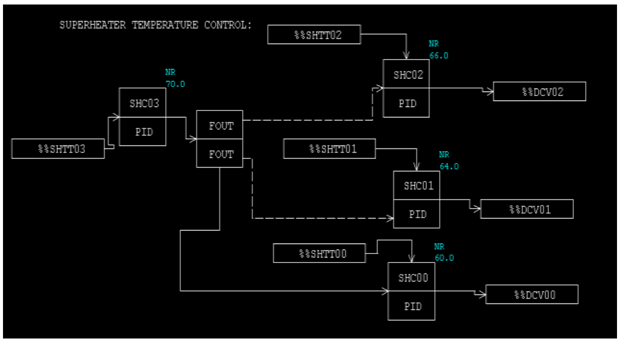

Fig.6. Control drawing builder of superheater temperature control

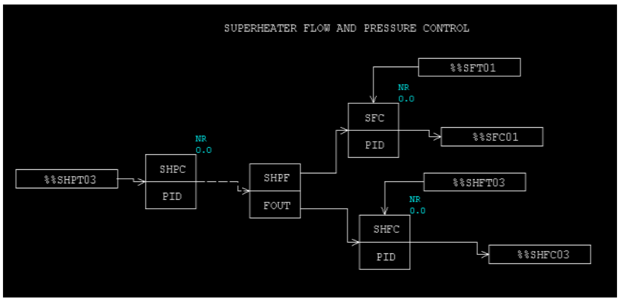

Fig.7. Control drawing builder of superheater pressure control

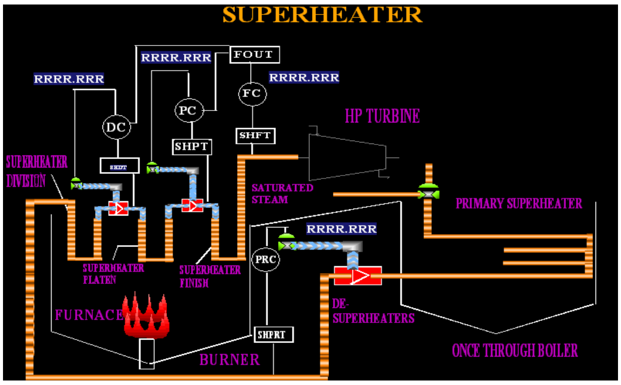

Fig.8. SCADA of superheater temperature control

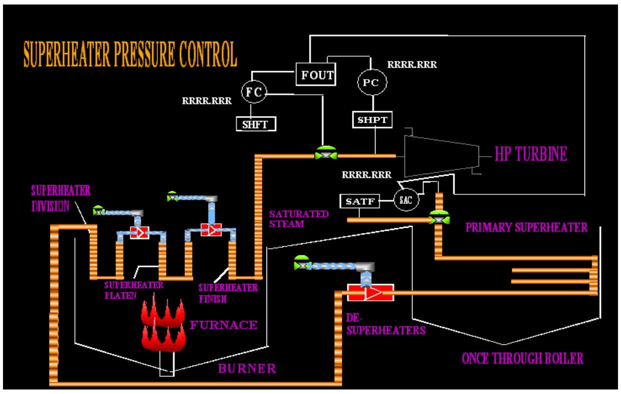

Fig.9. SCADA of superheater pressure control

4.2 Reheaters

Reheaters are similar to superheater with almost same steam outlet temperature and with a steam temperature about 25 % of superheaters. Reheater temperature can be controlled by injecting feed water into cold reheat steam side.

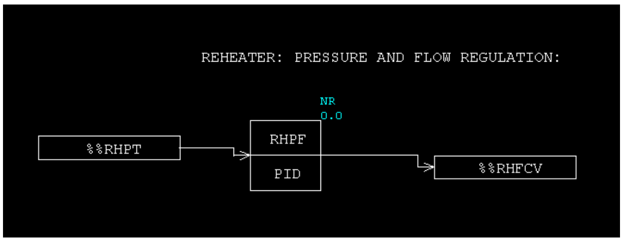

Fig.10. Control drawing builder of reheater pressure control

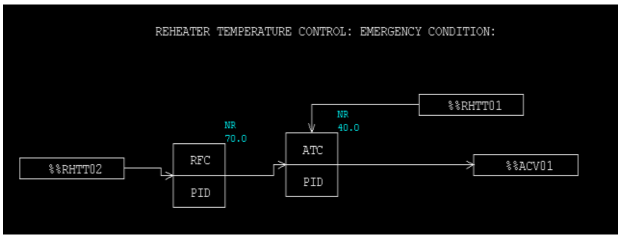

Fig.11. Control drawing builder of reheater temperature control

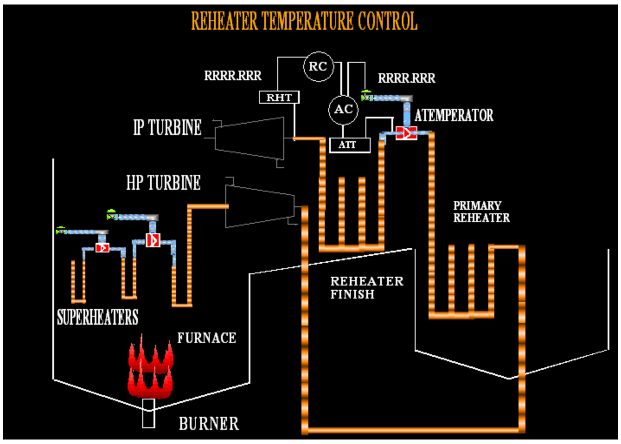

Fig.12. SCADA of reheater temperature control

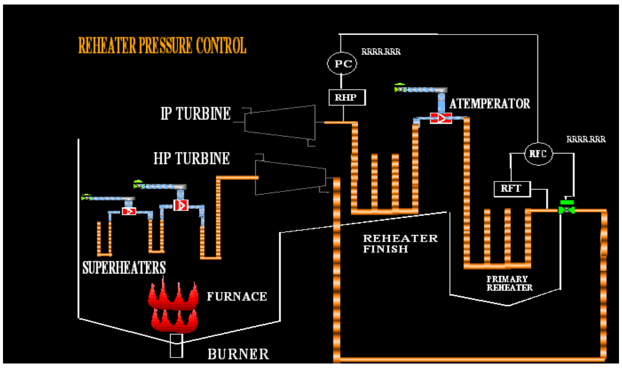

Fig.13. SCADA of reheater pressure control

4.3 Economiser

Economizer is a heat exchanger, which raises the temperature of the feed water leaving the highest pressure feedwater heater to about saturation temperature corresponding to boiler pressure.This is done by the hot flue gases exiting the last Superheater or reheater at a temp. Varying from **370°C to 540°C.**

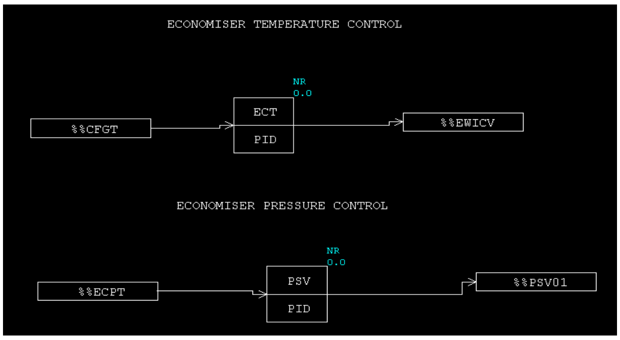

Fig.14. Control drawing builder of economiser

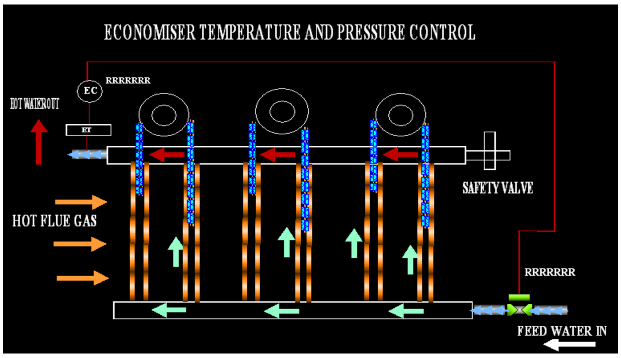

Fig.15. SCADA of economiser temperature control

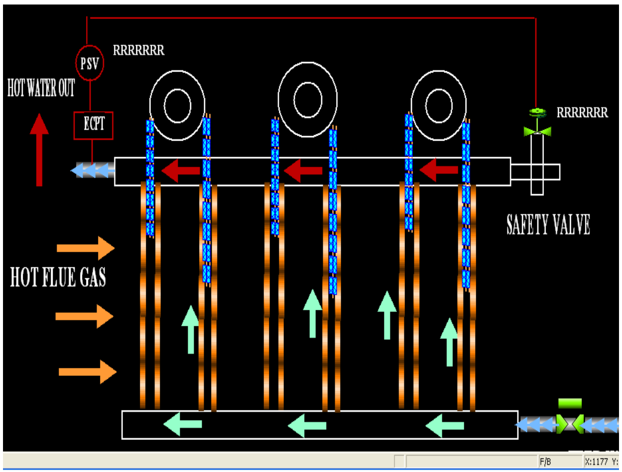

Fig.16. SCADA of economiser pressure control

4.4 Turbine and Condenser Parts

Steam turbines for USC steam conditions require application of advanced alloy steels for the HP and IP turbines and for the main and reheat steam admission valves.

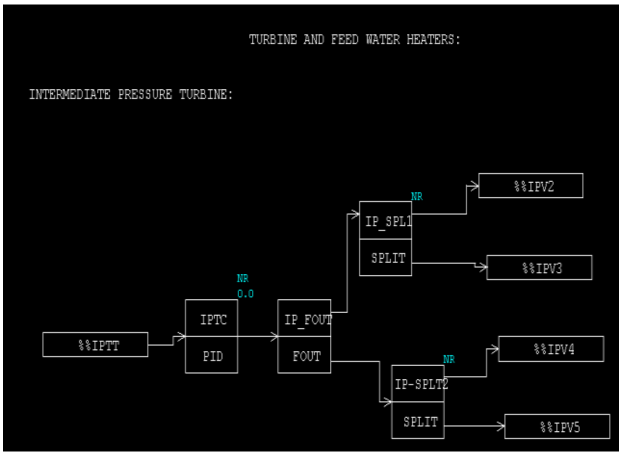

Fig.17. Control drawing builder of IP Turbine

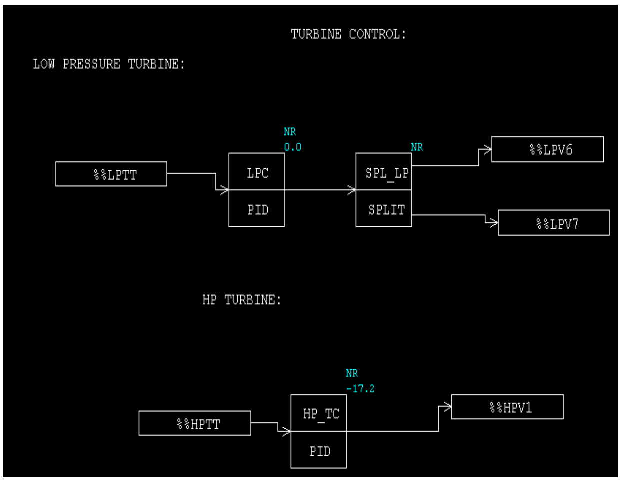

Fig.18. Control drawing builder of LP&HP Turbine

4.5. Condenser

Condensers are heat exchangers which convert steam from its gaseous to its liquid state at a pressure below atmospheric pressure. A water-cooled shell and tube heat exchanger installed on the exhaust steam from a steam turbine in thermal power stations is called as surface condenser.

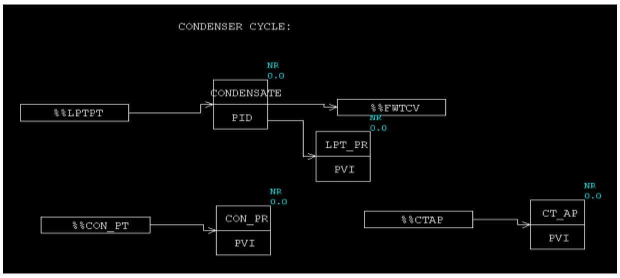

Fig.19. Control drawing builder of condenser

5. TREND WINDOW CONFIGURATION FOR USC POWER PLANT

Trend window is used for graphical representation of controller parameters with respect to time. In this paper, trend window of various parts of USC power plant is shown.

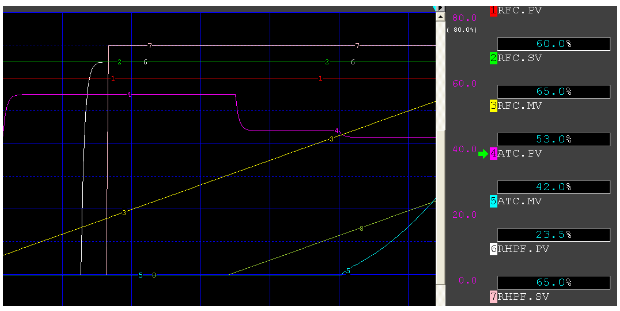

Fig.20. Trend window for Air/fuel ratio

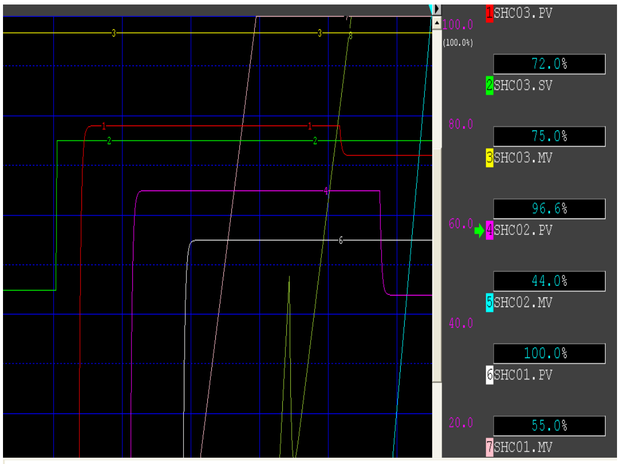

Fig.21. Trend window for Super heater temperature control

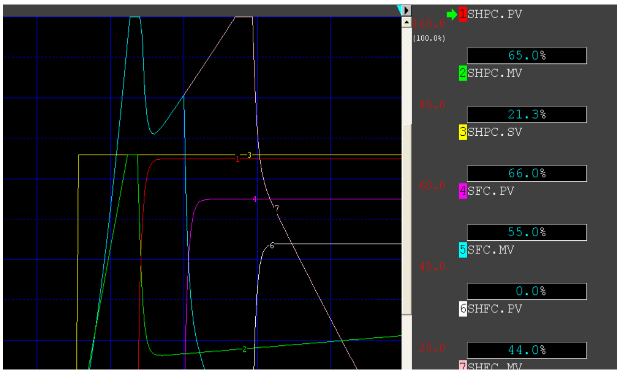

Fig.22. Trend window for Super heater Pressure control

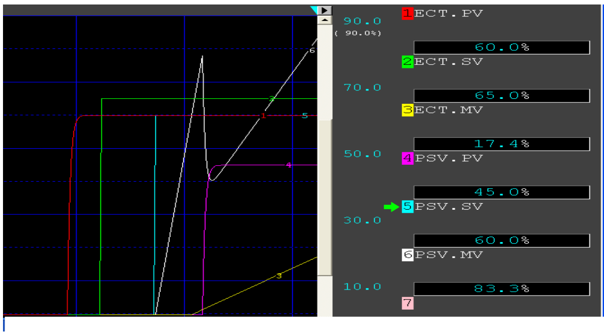

Fig.23. Trend window for Economiser

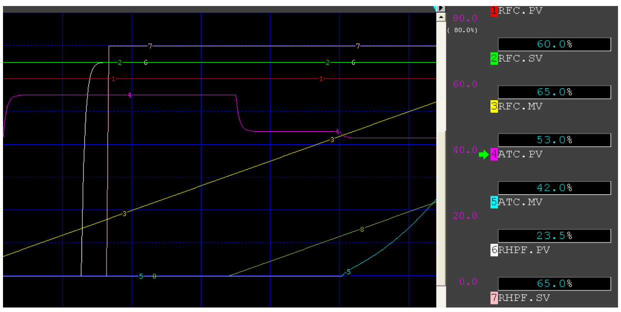

Fig.24. Trend window for Reheater

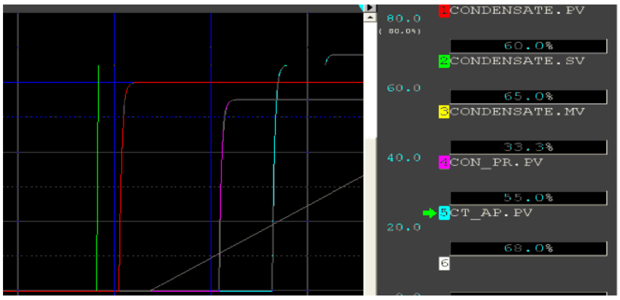

Fig.25. Trend window for Condenser

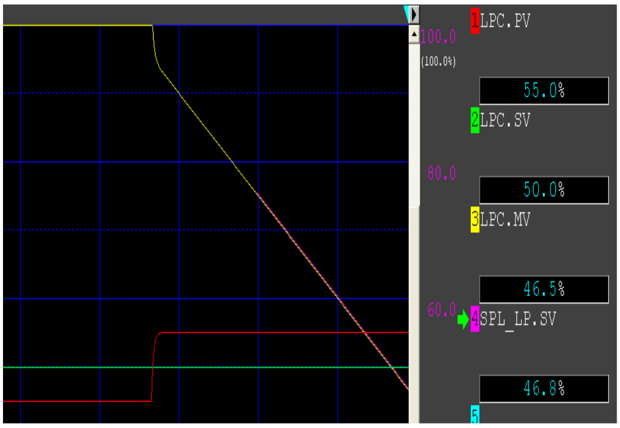

Fig.26. Trend window for Low pressure turbine

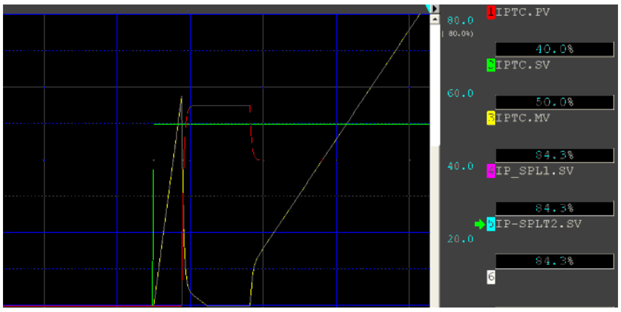

Fig.27. Trend window for Low pressure turbine

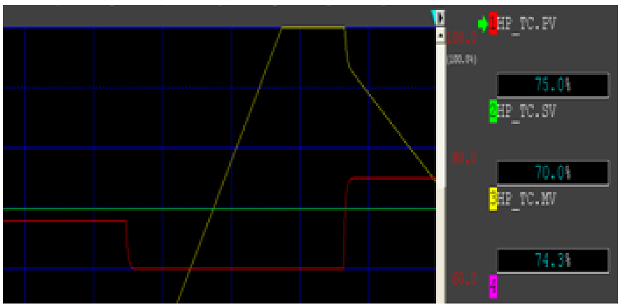

Fig.28. Trend window for Intermediate pressure turbine

6. CONCLUSION

Automated control system design is done for large scale ultra-super critical power plant using YOKOGAWA DCS (CENTUM CS3000).The overall efficiency of the USC power plant is improved by controlling and monitoring the pressure, temperature and flow through the various parts of the once through boiler (super heaters, reheaters, economisers) and also the air/fuel ratio is maintained automatically according to the demand. The temperature of the air preheaters are also controlled before it mixes with the burners to undergo combustion. Both open loop and close loop control is executed for the condenser process. Also turbine operating conditions is maintained by regulating feed water heaters automatically. Thus, the monitoring and control of the entire plant is done using DCS and it helps to reduce human intervention and increases the safety of the plant.

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