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Networked Control for Reducing Transients in Steam Generation

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ABSTRACT:This paper presents a scheme for precise control of boilers and steam systems and reduction in transients in case of abrupt change in the steam consumption by the downstream process plants. In large industrial complexes like refineries where the main source of energy and heating are steam and power generated by captive power plants, the tripping of huge steam driven machines in the process can cause undesirable transients in the steam systems. The transients which can be caused include rise/fall of main-steam header pressure and rise/fall in the boiler drum level. These transients in the system can cause serious problems like degraded steam parameters to other steam conditions if not controlled effectively. In worst conditions it can cause tripping of the steam generating boilers by very high or low drum level which is highly disastrous financially for such huge industries. The solution proposed in the following paper aims towards reduction in operator intervention required for precise boiler control in case of such unforeseeable events. This paper is mainly targeted for gas fired or liquid fuel fired boilers in which parameters can be manipulated and controlled quickly.

KEYWORDS: Boilers, Drum level control, Steam systems, Networked control system, Header pressure

I.INTRODUCTION

In large process industries like refineries and petrochemical complexes, the steam is generated by captive power plants and are transported by steam headers to the downstream plants in the complex. The downstream plants use the steam for many different purposes like in turbo driven compressors and pumps, process heating etc.

When running steadily, the total consumption in the steam equals the total production of the steam in the power plant by the header pressure control used in the boilers. Thus the boilers continuously caters to the steam demand while maintaining the pressure and temperature of the steam in the header. The main control in a boiler is the three element control for the steam drum level. The three element control takes drum level as a feedback, cascaded over the inlet boiler feed water flow and the outlet steam flow is used as a feed forward for the precise control of the drum water level. In case of change in the outlet flow of steam because of disturbances in the downstream plants, the feed forward signal will automatically enable the increase /decrease in the inlet boiler feed water flow.

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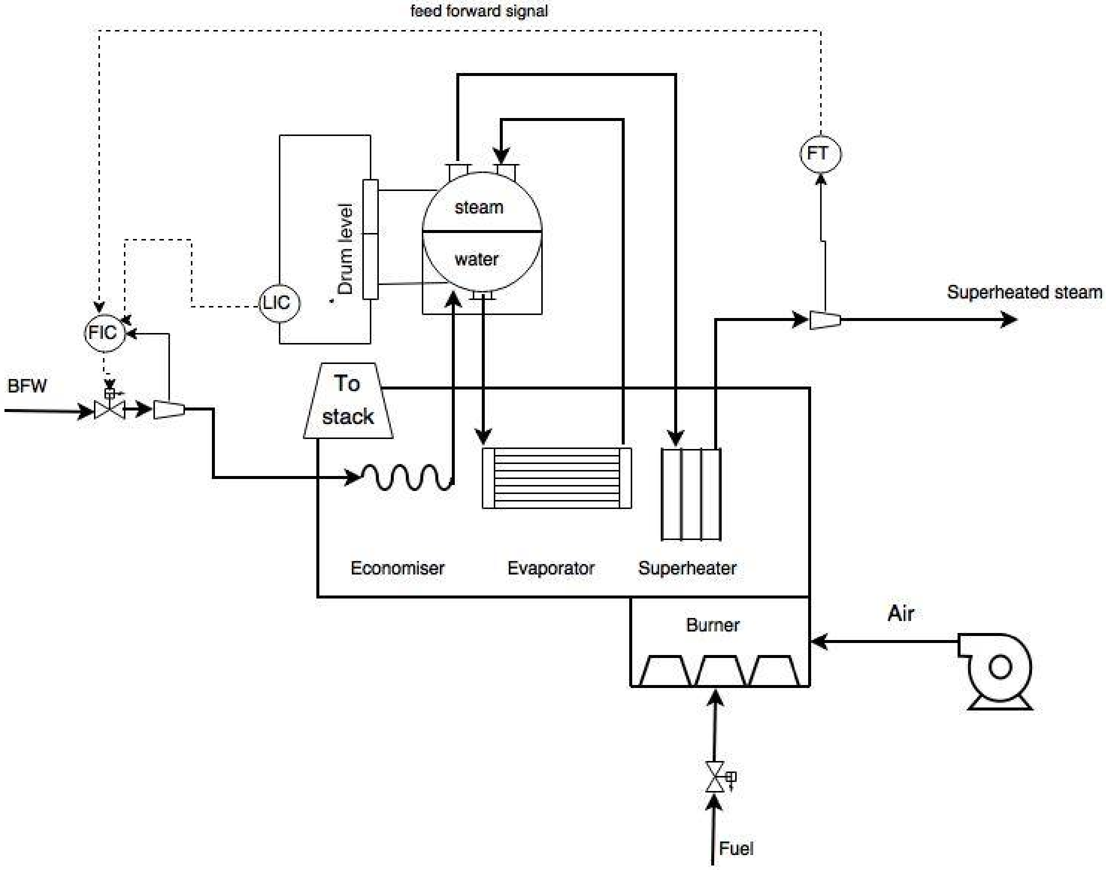
The currently used scheme for control of boiler drum level is schematically shown in the diagram below:



In such huge industrial complexes, there are a few major steam consumers like heavy steam driven compressors whichconsume a huge proportion of steam supplied by the captive power plants. In case of tripping of such heavy steam consumers, the rate of steam consumption suddenly falls and the header pressure rises. This rise in the pressure is transported in the whole header up to the power plant in a few seconds. This immediate reduction in the steam flow demand will cause the shrinking effect in the boiler which is the fast reduction in the boiler drum level. This happens because relating to the flow demand, excess heat is being supplied to the steam as the fuel flow was not reduced along with the reduction in the steam demand. If not addressed by the panel operator on time, this will cause the tripping of burners by the burner management system for maintaining safety.

This happens because of the time delay involves in the actuation of changes in the manipulated variable of boiler caused by the delay in transport of the change in steam header pressure and marginal compressibility of steam in the header. The manipulation of the parameters in the boiler starts only after the pressure disturbances reaches to the pressure sensor in the power plant.

II. OBJECTIVES

- Precise control of the boiler parameters
- Enabling unsupervised control of power plants
- Reducing transients in steam systems and making it robust
- Enabling the use of networked control system for futuristic control of process plants

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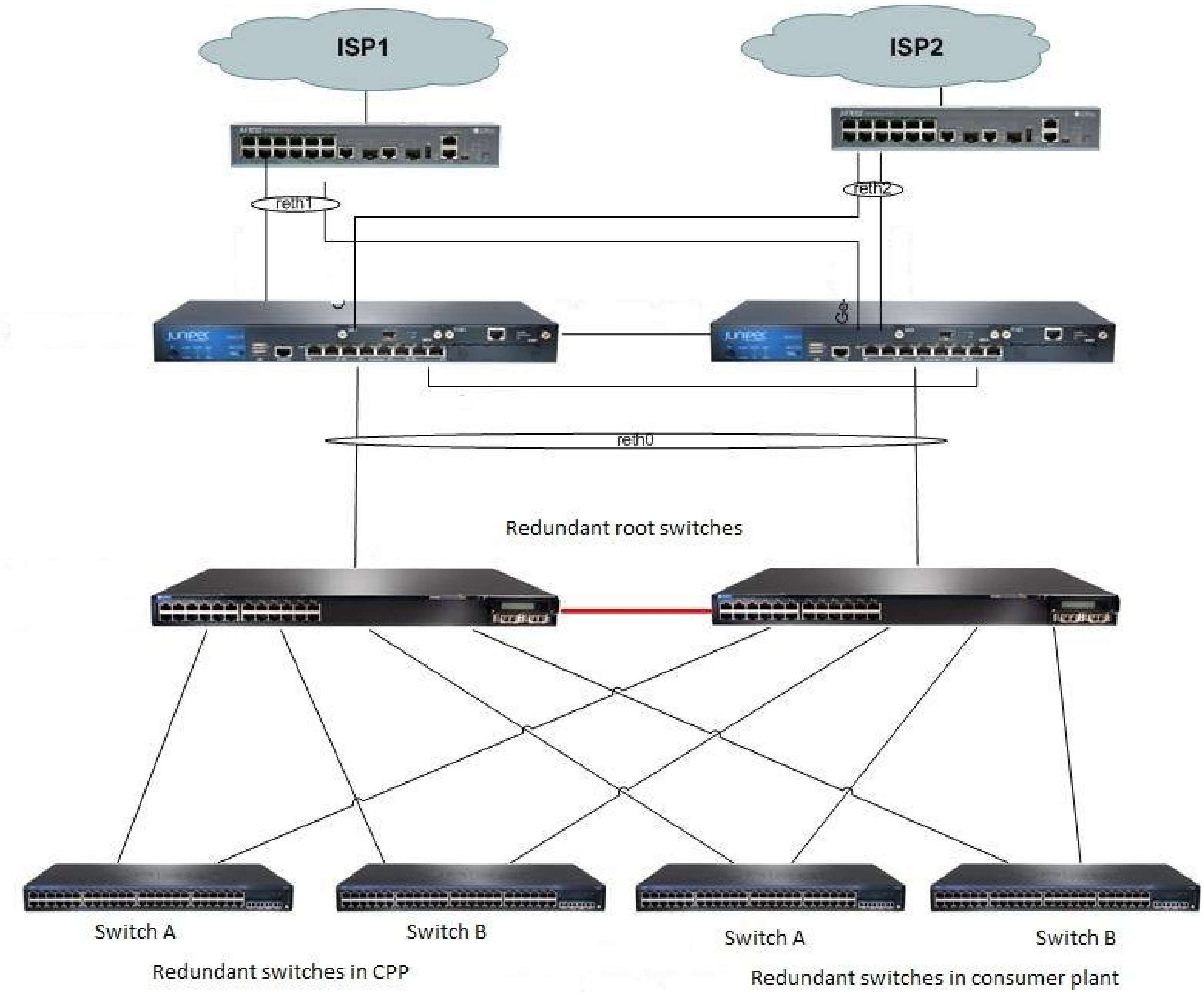
III. PROPOSED METHOD

The method meant to be proposed in this paper utilises the high speed fibre optic/copper mesh control networks used in large industrial complexes as a part of Distributed Control System. The network established is highly reliable and enables the connection of any pair of controller or nodes and communication of real time data in microseconds. The network architecture is shown in the image below:



The above network diagram shows only the network switches for power plant and one consumer plant. By using the above shown network topology all process plants are connected in a single root switch. This enables the data communication between controllers of different plants.

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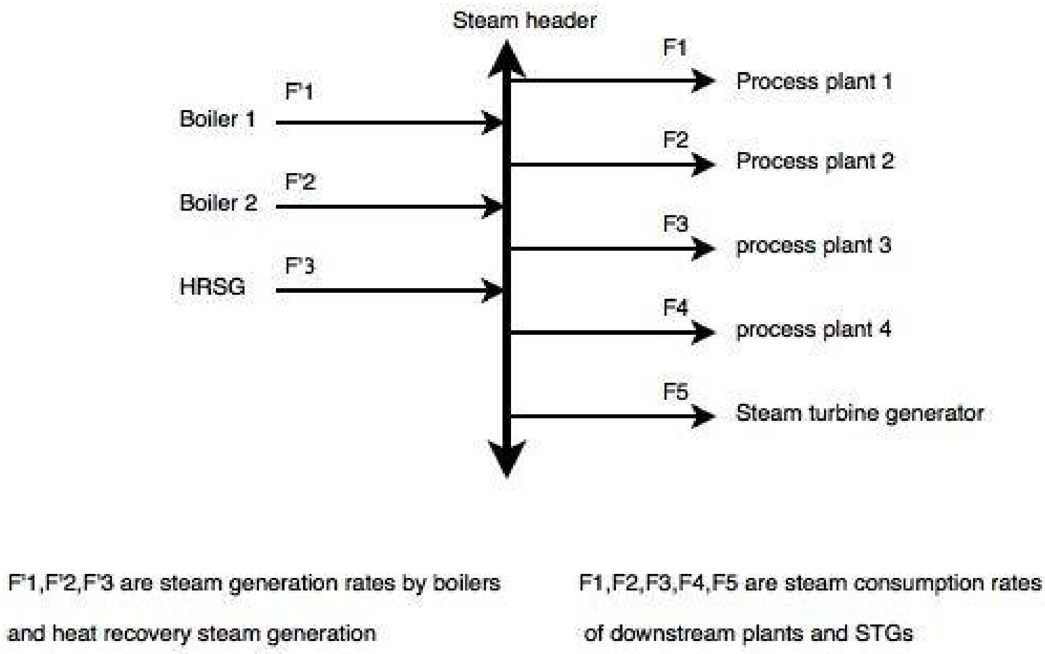
Consider the following steam path for the proposal of the solution:



Here the steam flows shown are compensated steam flows measured at the battery limit of the consumer plants using highly reliable redundant transmitters and the data is being captured by the controllers in distributed control system. In normal process conditions the flow values are in an optimum operating window and does not show a drastic and huge change in the steam parameters. Following equation can be written if the diagram shown is exclusive and no other steam consumer or producer is present.

$$F'1+F'2+F'3= F1+F2+F3+F4+F5$$

Now consider a huge compressor taking 10% of the total steam generation is present in the Process plant 1. It comprises of 75% of the steam consumed by the Process plant 1 which is 75% of F1. In case of tripping of the compressor, the steam consumption by the plant will reduce abruptly and will cause disturbances in the header pressure and ultimately the drum level.

To prevent this, the data of the flow transmitters at the battery limits of all plants can be used to generate an actuation signal which will take manipulative actions for prevention of the pressure and drum level transients.

The control logic implemented in the controller in the power plant will first add up the steam flows at the battery limits and generate a signal for net flow consumption at consumer end. And continuously monitor the signal in real time.

$$F(\text{net consumption at consumer end})= F1+F2+F3+F4+F5$$

The above signal can be used to calculate the rate of change of total steam consumption.

$$\frac{\Delta F}{\Delta T} \geq x\, TPH/sec$$

$$And\ \Delta F \geq y\, TPH$$

Where x and y are predefined values determined by experimentation.

If the above signals occurs the sudden reduction in the steam flow is confirmed and can be used for actuation signal. Also 2 out of 3 signals of tripped feedback for all major steam consuming equipment can be fetched over the network for better decision making.

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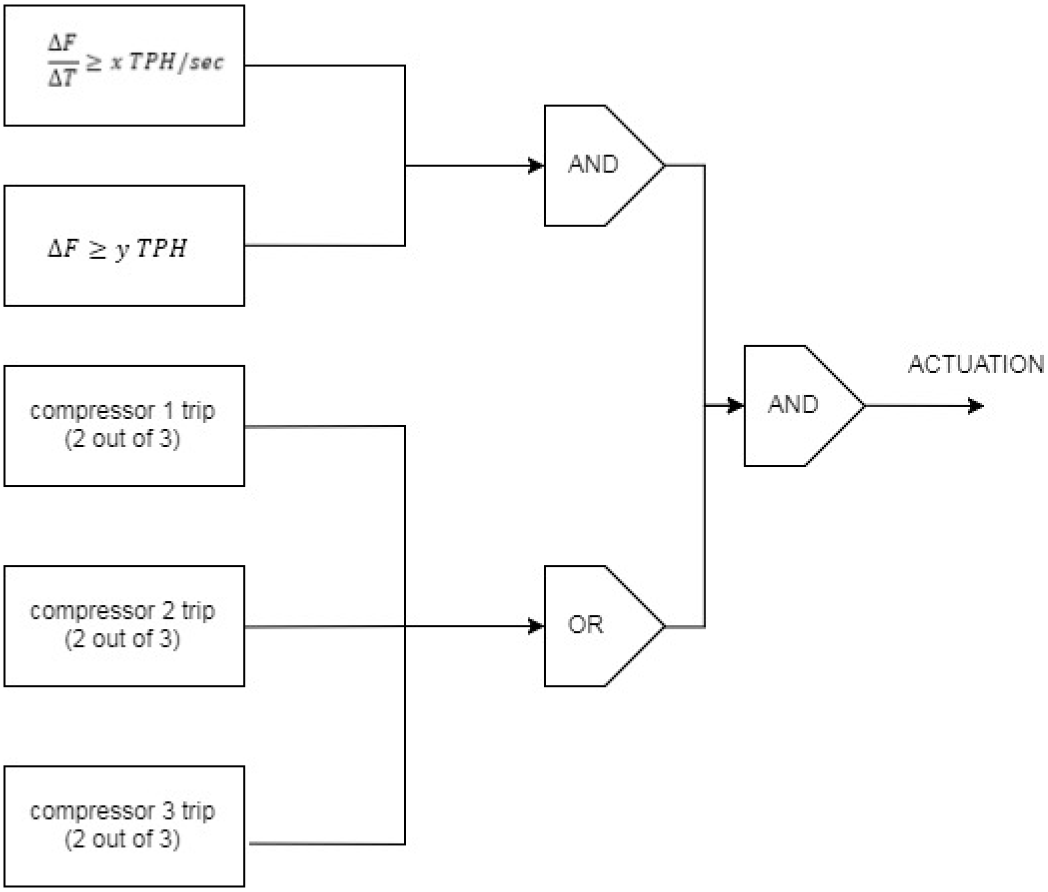
Following logic can be implemented for increasing the reliability of this algorithm and eliminating chances of false activation:



The actuation signal generated will manipulate the following parameters:

- Immediate reduction in the fuel flow in the burners
- Immediate reduction in the feed water flow
- Immediate actuation of the pulse command of predetermined time to continuous steam blow down or pressure reducing stations.
- Step increase in the load set point of the steam turbine generators and similar decrease in the load of the gas turbines and other non-steam power generation sources.

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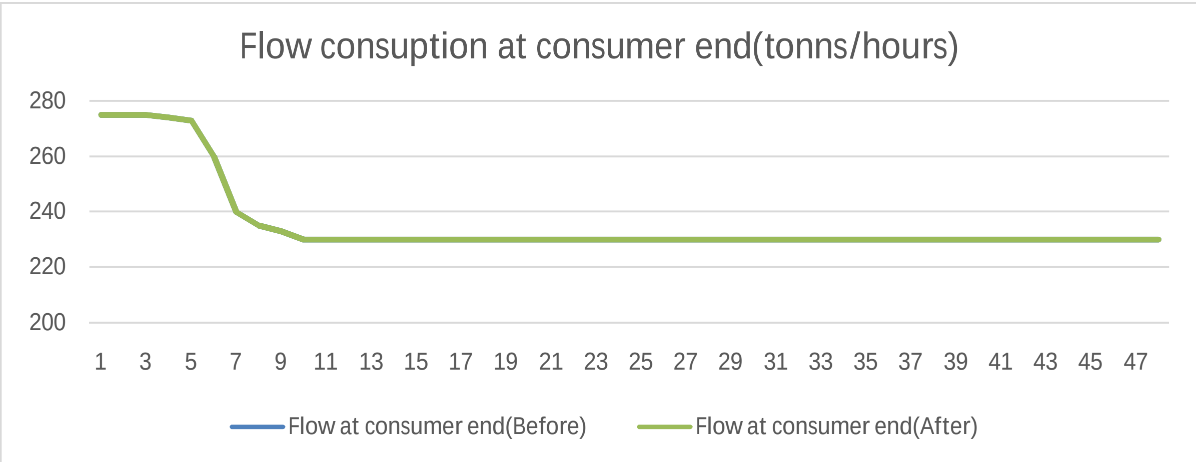
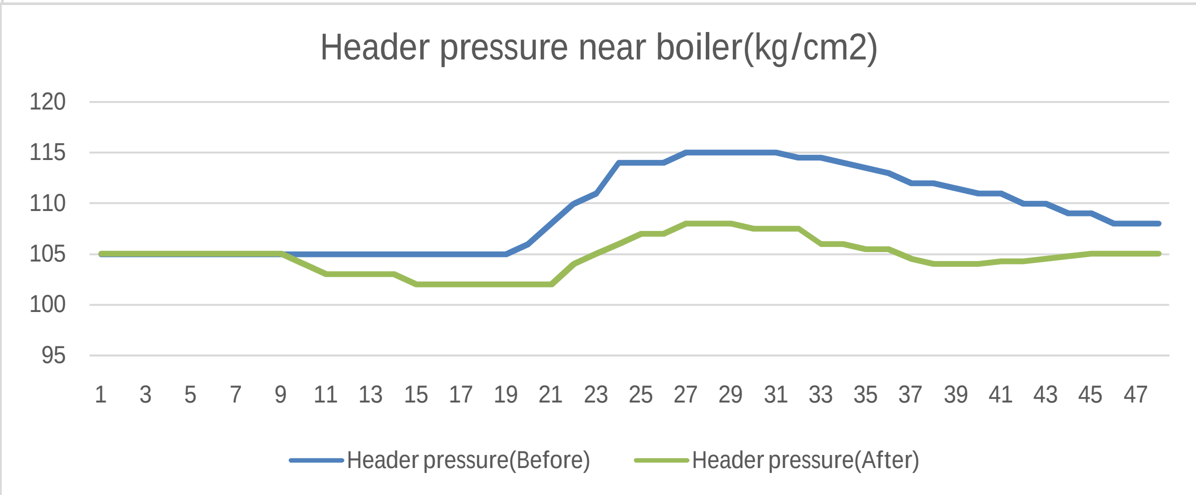
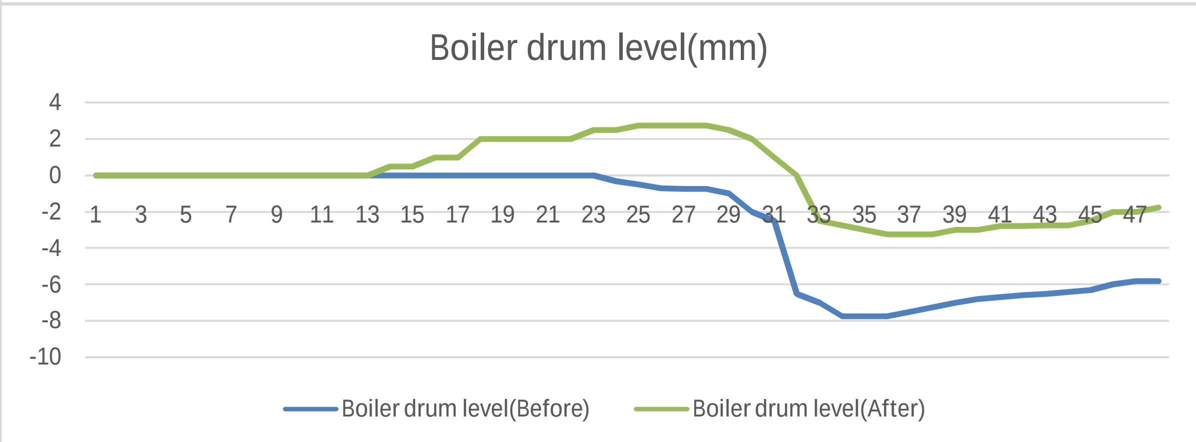
IV.PROPOSED SYSTEM PERFORMANCE

Example of the graph of header pressure and boiler drum level for one of the boilers in the steam network is shown in the following graph **(Proposed):**







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If the experimental parameters are selected meticulously and the tuning of all the controllers in the boiler control loops are fine-tuned, above shown improvements can be achieved and it can reduce the quick attention and action of the panel operator required to maintain the drum level and header pressure in the operating window.

V. CHALLENGES AND FURTHER RESEARCH

The major challenges in the implementation of the proposed method are:

- Fine tuning the experimental values for getting the required system performance, which may vary depending on the capacity of the complex.
- Effects of the actuation on the electrical systems and transients generated in it because of step change in the set points. The loading of STGs and unloading of gas turbines and other generating techniques may not be equal which can cause transients. Extreme care must be taken for preventing disturbances in electrical systems because disturbances and tripping in electrical systems can cause even more losses.
- One more challenge is the robustness of the experimental parameters in case of consumption flow variations of different magnitudes because of different load demands of downstream steam consumers.

The scope for further research are following:

- Application of the above proposed networked control system to other chemical processes which involve interconnections between plants.
- Developing more automation algorithms and making power plants fully automatic and unsupervised or minimally supervised.

VI.CONCLUSION

The suggested methodology for reducing transients in boilers and power generation systems is one of the steps towards unmanned, unsupervised and safest industrial operations.By developing algorithms like these and applying to all possible processes, the industrial processes as well as other networked systems can be made more and more automatic and hence efficient and safe.

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