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Modeling of condensate water system in a nuclear power plant with new control strategy using Dymola/Modelica

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ABSTRACT: This paper is focused on modeling and introducing a new control strategy for a condensate water system. Current control strategy of the system is simple feedback control system with one PID controller. Results of current control strategy were taken into account for improvements in terms of system stability, valve movements and unwanted transients. Problems found in condensate system were; large variations in process variable, extra movement in valve positions and inefficient opening of valves. Simulation model with current control strategy and results as of real power plant was created and validated, as new control strategy can be applied and results can be compared. The main recommendation to improve the control system performance was found through PID cascade control strategy that could assist the current controller. The recommendation was evaluated by designing and implementing the cascade control strategy on the Dymola simulation model. Simulation results pointed out considerable increase in system performance according to the requirements of Ringhals (Vattenfall) AB Sweden.

KEYWORDS: Condensate, valve movements, validated, Dymola, transients.

1 INTRODUCTION AND OBJECTIVES

This research is done in Vattenfall AB Sweden which is a leading European power generation company, whose main product is electricity. After major maintenance efforts for an extensive modernization of monitoring, control equipments and upgrade from analog to digital I&C system it was observed that few valves in different control loops had some strange behaviors. These uneasy and constant movements in the valves will probably wear out the life of the valve even before its expected time, which would result in a large maintenance cost and shutdown. In order to even service these valves, part of the turbine or the entire turbine must be taken out of service which will lead to a large repair cost. These valve movements and resulting flow transients will further carry to unnecessary oscillations and challenges to the other parts of the plant, thus reducing overall strength and durability. The preliminary aim of this research is to perform a detail study of control loop (condensate water system) at nuclear power plant documented by Westinghouse Electric Corporation. Subsequently, after studying details of this system the ultimate goal was to investigate how the overall performance of condensate system could be improved by implementing a much more refined control strategy. The recommended control strategy should maintain performance, minimize valve movement and the range of level amplitude should be allowed to change $\pm$ 5% [1]. Another side goal of this research is to implement a tracking logic in the simulated model such that, whenever main valve or pump breakdowns, emergency valve should open instantly. After implementing the recommended control strategy, objectives are achieved as required. To achieve these tasks, a simulation model was developed for the control loop to construct and evaluate the new control strategy.

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1.1 CONDENSATE WATER SYSTEM (DRAINAGE SYSTEM)

Condensate water system contains a water tank whose level is controlled by two valves main valve and emergency valve. Basically, this control system in nuclear power plant has total four pair of valves so it is obvious that the modeling and controlling improvement techniques implemented on one pair of control loop can also be implemented on other pairs.

As two valves (main and emergency valve) are connected to control the water flow from tank, main valve (V141) is operating under a normal condition when PID controller output is 50% or below 50% and the emergency valve (V131) is used when PID controller output increases above 50%. PID (proportional, integral and differential) controller which is previously implemented in this control loop is generating a control signal to stabilize given set point valve (demand signal or required level of the tank) and this PID controller's output is controlling the positions of both the valve accordingly. The strict condition for these valves are that when the PID controller output increases from 0% to 50% then control valve V141 should start opening from 0% to 100% respectively. Further, if the controller output increase above 50% then the emergency valve V131 should start opening in a similar manner as V141. Likewise, once the controller output start decreasing, emergency valve V131 should be fully closed first then valve V141 should start to closing. The maximum operating power is 450MW; power for LTDP (low pressure drainage pump) to start is approx 230MW and its stops at 15% of the maximum power which is 67.5MW. Fundamental reasons causing instability are unwanted variations in existing controller, which causes variation in valves and main reason is that existing controller has no knowledge of tank outflow measure and variations in input flow. Condensate system plays significant role in power plants and due to its failure whole power plant can collapse [2].

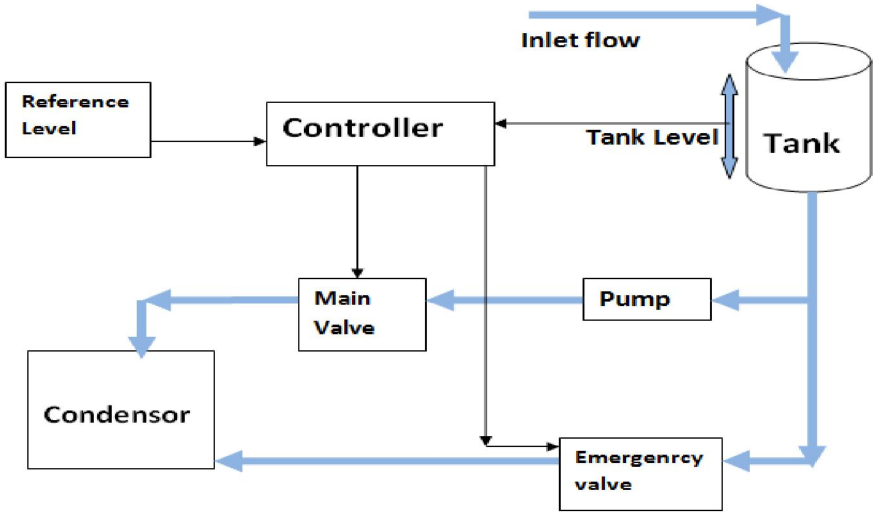

Fig. 1. General block diagram of condensate water system

2 SIMULATION MODEL

A simulated model of the system is developed with detailed modeling design in the simulation language called Modelica using its graphical tool Dymola. The entire control loop and its each model component are modeled after studying and understanding its technical AutoCAD drawings, documented data, system description and datasheets provided at Ringhals nuclear power plant. The model is built in a hierarchical manner and every component and complete model is validated against the data available from the real plant. Simulation model with new control strategy is given in figure2

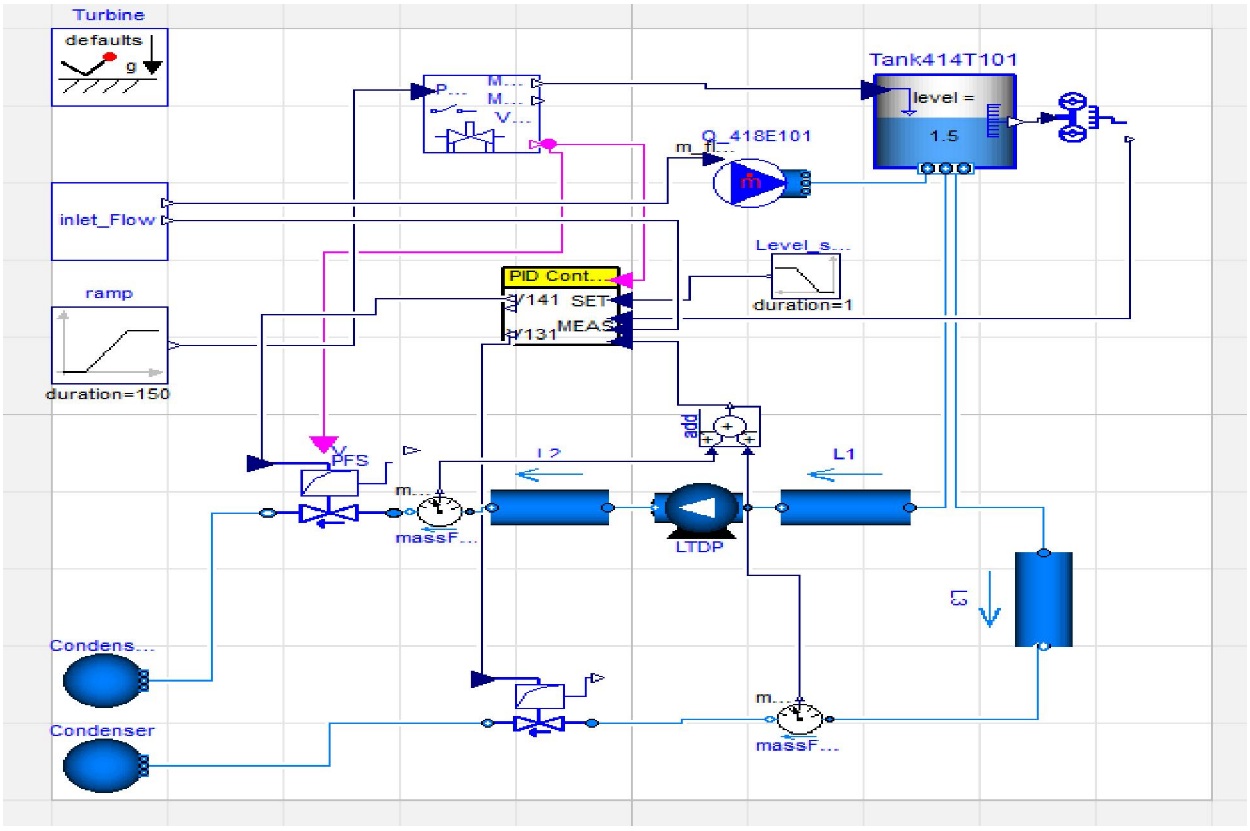

Fig. 2. Simulation model of condensate water system in Dymola/Modelica

Main simplifications in model are turbine logic, valves and inlet flow. In turbine logic block, initial signal distribution is made on basis of input power; user decides start and stop of power and pump from this block. Simplification in valves is also made in sense that simple valves were used from Modellica library and their transfer function were used such that; valve output should be acting similar to real valve in plant. In valve V141, characteristic curve was introduced to make soft valve similar to real valve. In real plant main flow to tank T101 is coming from valve V287 and moisture separator. These flows are simplified in sense that flow from valve V287 is created using a table and flow from moisture separator was taken as constant value because it changes very slightly and mostly remains close to chosen value that is 50kgs/sec. This simplification was done because V287 is further connected to other components like tank 102, pumps and so on and it is not possible to model all [3].

2.1 Simulation model description

Figure 2, shows simulation model of a condensate water system; main objective of this model is to control level in the tank at a desired level using control valve and emergency drainage valve for water drainage. Model is operating at maximum input power of 450 MW, tank input pressure from turbine logic is approx 4.5 bar and input flow from valve V287 (approx 73kg/sec) and from moisture separator is 123 kg/sec. Inlet flow block (V287 and moisture separator) is then connected to mass flow component to generate and supply water flow to the tank. Level in the tank is measured with level gauge and this measured level is applied to PID controller where it compares measured level with desired level (set point) and generates control signal for both connected valves. Control valve V141 is the main valve and operates in normal conditions while V131 is emergency valve which operates when controller output increases above 50%. Both valves are connected with PID controller through appropriate logics with the help of different Modelica blocks and their operation is according to control signal generated. PID maintains required level in the tank through valves (V141 and V131) where LTDP is used to pump water from the tank through control valve V141. Finally flow from both valves ends at condenser in the simulated model as shown in figure 2. Implemented new PID cascade control strategy (Inner model of PID Control block in figure 2) can be observed in figure 3 below

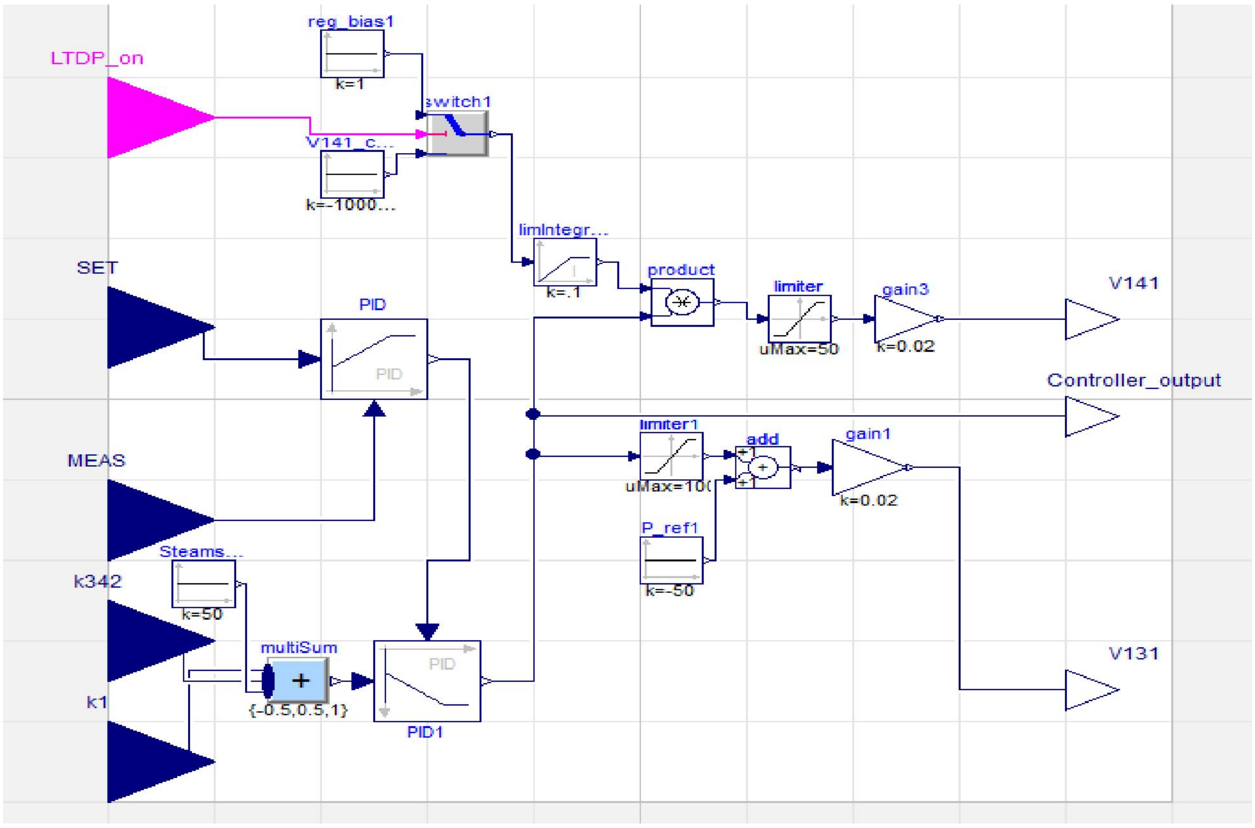

Fig. 3. PID Cascade controller design in Dymola

2.2 Simulation model boundaries and simplifications

As this condensate water control loop model does not cover the entire system of the plant except the required particular section, so the other parts of the system which are affecting this loop in a smaller manner are modeled as approximate constant values. Therefore, condenser is modeled as a constant pressure source and its pressure normally varies a very little with turbine power and with sea water temperature. Moreover, flow fluctuations are expected to be very small and slow to cause any pressure change, so it is neglected in this model. The pressure in T101 was modeled as a function of turbine power and is independent of the flow to the tank. The tank is in contact with a large steam volume and the level fluctuations in the tank are relatively small. The dynamic behavior of steam pressure is much slower than the regulating system so the error in the model is considered negligible.

3 Model Validation

Simulation model of the condensate water system with validated valves and pump was validated against the real plant data all initial condition of real plant and simulation model are approximately same. For this procedure, real plant parameters and specifications were set similar in the simulation model such as PID control parameters (P=1.67, I=36, D=.00001), input power of 450MW, real input flow data of value V287 and with same set point [4]. Model was simulated with these parameters and the evaluated data was compared with the real plant data as shown in Figure 4. To get these results initially developed model in Dymola with one PID as similar to real system was simulated with same above mentioned values, it was to validate that simulation model works in similar manner as of real plant, and Figure 4 is a combined plot of simulated model and real plant developed in Matlab.

From Figure 4, it can be observed that process variable of the simulation model is oscillating in the start as compared to the process variable of the real plant. Reason for the process variable of the real plant being stable is that the obtained data is of running plant where the process variable was already in steady state compared to simulated model response. Initially control signal is high which causes high opening degree of V141 and due to which level oscillates in the start.

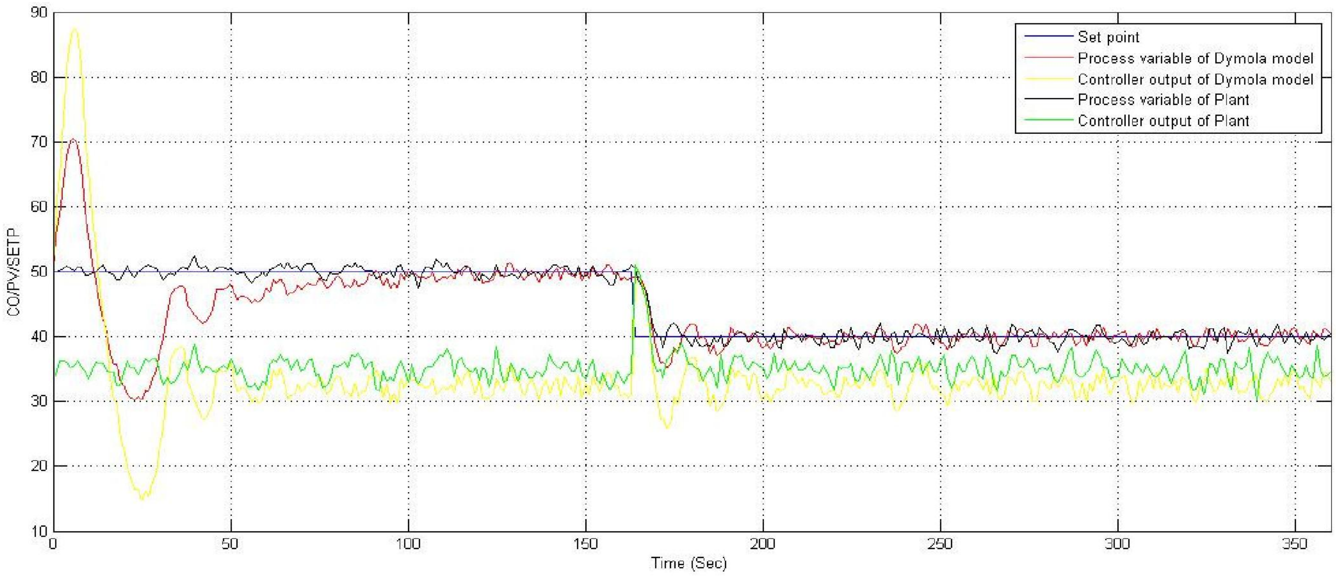

Fig. 4. Condensate water system validation step response test.

Level starts to reach the desired value as controller reads error signal and generates signal for actuators, it takes approx 50 seconds for level to reach at required set point where it follows set point with similar fluctuations as of real plant. Moreover, it can be analyzed that the dynamics of the Dymola model response is relatively close to the real plant.

4 RESULTS

Model response with cascade control strategy is shown in Figure 5. It can be observed that level is following the desired set point with low fluctuations (max +-2%). There is a step change at 225 seconds from 50% to 40%. As required level drops 10 units, controller observes error signal and generates a new signal to reach the new set point value. As it is always been a give and take between controller speed and performance, in our case both controller speed and performance are good enough.

Small fluctuations in process variable (measured tank level) are due to change in input flow with time, inflow is varying continuously and remains close to 123 kg/sec but due to varying amount level of the tank changes and level sensor reads level every second and due to which small fluctuations appear.

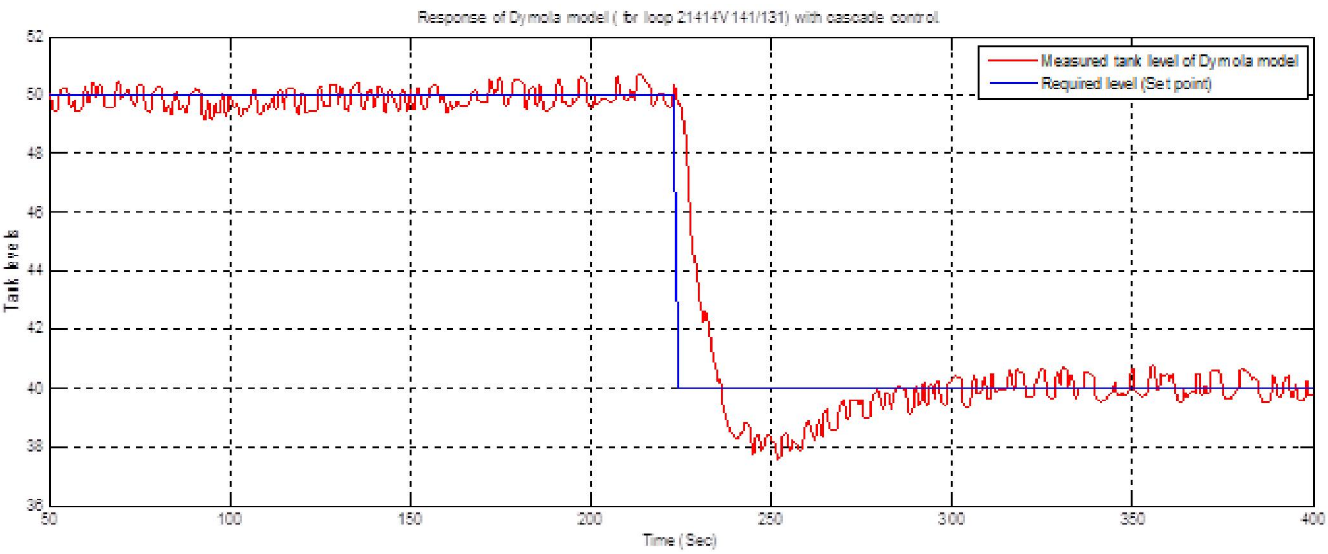

Fig. 5. Response of condensate water system simulation model

In Figure 6, response of simulated Dymola model with cascade control design is compared with the response of real plant with existing single PID feedback controller. The step change is introduced at 225sec as a decrease from 50% tank level to 40%. Real plant response and simulated cascade control output can be seen in Figure 6. Data used for real plant is of same control loop but at different time so there is different step change, however it does not affect results in any form but only used to see how better improved results are. There is a clear improvement in level response; a lot of oscillations have been eliminated due to the compensating behavior of the cascade control. From the graph, we can see that cascade control reacts in an appropriate way. Though, the speed of the cascade controller is similar but there is a longer under-shoot compared to real plant but this under shoot is well within the reasonable limits of this system.

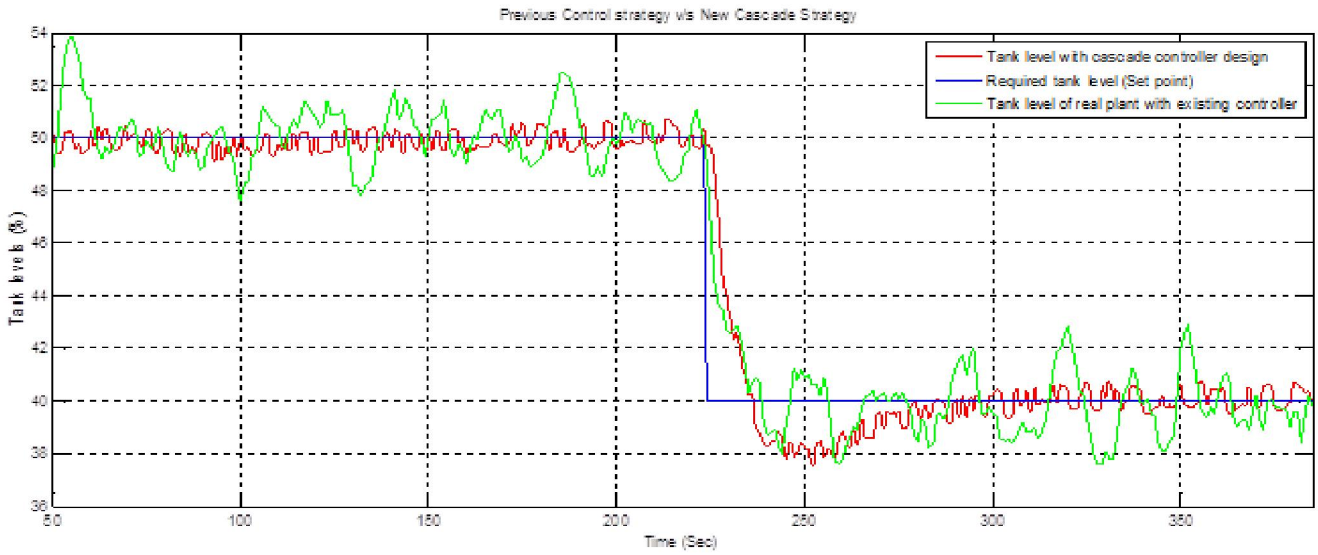

Fig. 6. Comparison between existing and suggested controller technique.

Figure 7 shows efficient opening of emergency valve when LTDP trips at time 200 seconds. LTDP is tripped by force at mentioned time, due to which main valve V141 starts closing and controller increases its output to put emergency valve V131 in operation as tank level can be maintained. LTDP trip occurs when power decreases below 230 MWs and again it starts operation when power increases above 230 MWs.

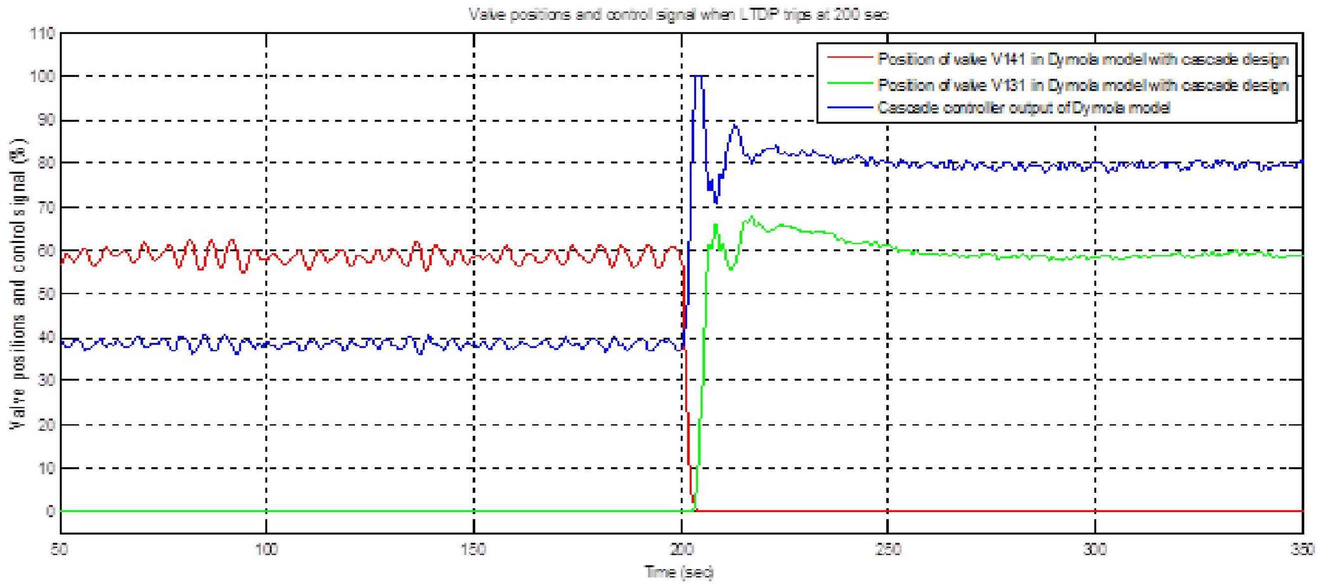

Fig. 7. Efficient opening of emergency valve when LTDP trips at 200 sec

5 CONCLUSION

Simulation model was validated against real control loop data at different transients and has showed that the simulated model is a decent approximation of the real plant with relatively similar dynamics. Once the model was analyzed, variations in inlet flow to tank were found to be the major disturbance, preliminary solution was to design an accurate inlet flow (from V287 and moisture separator) to the tank and add some filtration to existing PID controller but it was not sufficient to meet required results, after studying different control strategies it was concluded that PID cascade technique will be more appropriate for this control loop, other techniques were not suitable due to complexity of system and due to lack of accurate mathematical model. Most promising solution was to implement PID cascade design in connection to existing controller. Simulation results using cascade design showed that the controller is more responsive and stable. It behaves smoothly during step changes and huge flows and simulated results using cascade control showed more stable system performance and results.

REFERENCES

[1] Carl Ressel, “Modeling and Control of Feed Water Systems in a Pressurized Water Reactor,” Master Thesis, Chalmers University of Technology, 2011.

[2] Zhang Yongsheng, Ma Yunyi, and Tang Ying, “Research on the condensation and feed water control system for nuclear power plant,” *2010 International Conference on Computer Application and System Modeling (ICCASM)*, vol. 3, pp. V3-63-V3-66, 22-24 Oct. 2010.

[3] Douglas J. Cooper, “The Cascade Control Architecture - Practical Process Control by Control Guru”, 24 Nov. 2013. [Online] Available: http://www.controlguru.com/2007/070607.html

[4] R. Vilanova and O. Arrieta, “PID tuning for cascade control system design,” *2008 Canadian Conference on Electrical and Computer Engineering, CCECE 2008*, pp. 001775-001778, 4-7 May 2008.

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