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SIMULATION A DYNAMIC MODELING THEORY OF STEAM TURBINE BASED ON AGENTIC A LOGARITHM

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ABSTRACT

In the present paper, a thermodynamic analysis of steam turbine type (K–800–23.5–0.034), power plant has been carried out. The power plant system was simulated and a detailed parametric study undertaken, which involved environmental parameters, such as the temperature of cooling water entering the condenser and the inlet ambient air temperature, as well as some other operational parameters, such as excess air percentage and stack exhaust temperature. It was noted that the excess air percentage should be maintained below 10% and stack exhaust temperature should keep to a minimum. A detailed analysis of exergy losses was made. It was observed that the relative exergy losses in the combustor and evaporator are the highest compared with other parts of the plant. Finally, many recommendations have been suggested for improved plant performance. The present study helped to identify plant site conditions that cause losses of useful energy to take place and also helped to resolve some problems encountered in steam turbine type (K–800–23.5–0.034), capacity unit. Developing nonlinear mathematical models based on system identification approaches during normal operation without any external excitation or disruption is always a hard effort, assuming that parametric models are available. This study included on using soft computing methods would be helpful in order to adjust model parameters over full range of input–output operational data. In this study, based on energy balance, thermodynamic state conversion and semi – empirical relations, Different parametric models are developed for the steam turbine subsections. In this case, it is possible the model parameters are either determined by empirical relations or they are adjusted by applying genetic algorithms as optimization method. Comparison between the responses of the turbine – generator model with the responses of real system validates the accuracy of the proposed model in steady state and transient conditions. The study presents the usage of the cycle – tempo and Matlab/Simulink package to implement the model of the power plant unit (VPPM), which is the basis for the Virtual Power Plant (VPP). This environment facilitates virtual modeling approach at component and system levels

KEYWORDS: Steady state, Transient conditions, Exergy losses, a gentic a logarithm.

INTRODUCTION

The growing demand of power has made the power plants of scientific interest. The steam turbines have been widely employed to power generating due to their efficiencies and costs. With respect to the capacity, application and desired performance, a different level of complexity is offered for the structure of steam turbines. For power plant applications, steam turbines generally have a complex feature and consist of multistage steam expansion to increase the thermal efficiency. It is always more difficult to predict the effects of proposed control system on the plant due to complexity of turbine structure. Therefore, developing nonlinear analytical models is necessary in order to study the turbine transient dynamics. These models can be used for control system design synthesis, performing real-time simulations and monitoring the desired states [1]. Identification techniques are widely used to develop mathematical models based on the measured data obtained from real system performance in power plant applications where the developed models always comprise reasonable complexities that describe the system well in specific operating conditions [2]. System identification during normal operation without any external excitation or disruption would be an ideal target, but in many cases, using operating data for identification faces limitations and external excitation is required [3]. Assuming that parametric models are available, in this case, using soft computing methods would be helpful in order to adjust model parameters over full range of input–output operational data. Genetic algorithms (GA) have outstanding advantages over the conventional optimization methods, which

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allow them to seek globally for the optimal solution. It causes that a complete system model is not required and it will be possible to find parameters of the model with nonlinearities and complicated structures [4]. In the recent years, genetic algorithms are investigated as potential solutions to obtain good estimation of the model parameters and are widely used as an optimization method for training and adaptation approaches. Rekha Rajan et. al, [5], Investigated the effectiveness of different controllers for the speed control of Tandem compound single reheat steam turbine. The speed of a Tandem compound single reheat steam turbine is controlled using the proposed MPC (model predictive control) controller. Then the results of the comparison of the proposed controller with the traditional PID controller and fuzzy PID controllers were also presented in this work. According to the simulation results in MATLAB, showed that the proposed MPC can improve the robustness and small overshoot and fast response compared to the conventional PID and fuzzy PID. In the area of turbine speed control the faster response to research stability, the better is the result for the plant.
M S Jamel et. al, [6], carried out a simulation of a 200 MW gas – fuelled conventional steam power plant located in Basra, Iraq. The thermodynamic performance of the considered power plant is estimated by a system simulation. A flow – sheet computer program, “Cycle – Tempo” was used for this study. The simulation results were verified against data gathered from the log sheet obtained from the station during its operation hours and good results were obtained. Operational factors like the stack exhaust temperature and excess air percentage were studied and discussed, as were environmental factors, such as ambient air temperature and water inlet temperature. In addition, detailed exergy losses were illustrated and described the temperature profiles for the main plant components. Orosun Rapheal and Adamu Sunusi Sani, [7], modeled physical boiler system was modeled as a multivariable plant with two inputs (feed water rate and oil – fired flow rate) and two outputs (steam temperature and pressure). The plant parameters ware modeled by identification based on experimental data collected directly from the plant. The routines of system identification toolbox with structure selection for autoregressive moving average together with recursive least square (ARX) were used to identify the model. The identified ARX ode was validated using Akaike's Final Prediction Error (FPE) criterion. The identified model was further subjected to test, using the validation input data; simulated model outputs for both temperature and pressure agree closely with the actual plant outputs with error of 8% and 9% respectively. Furthermore, Proportional Integral Derivative (PID) Controller was developed to control the identified model. Simulation studied was carried out; the results obtained indicated the effectiveness of this technique. The controller was able to track the temperature and pressure set points steadily and rapidly. Von cand. Ing. Jordi Bassas, [8], dealed with the development of a thermo – hydraulic model of a Nuclear Power Plant steam turbine and its implementation in the system code ATHLET. The model was based on Stodola’s cone law and simulated the pressure drop and the enthalpy drop along the different turbine stages as well as the steam and water extractions. The influence of the steam and water extractions on the turbine behavior as well as the importance of an accurate model for the steam and water extractions were carefully explained. Heat and mass balances of the Nuclear Power Plant Philipsburg 2 (located in Philipsburg in Karlsruhe (Germany) are presented. Two units, the first a BWR (boiling water reactor) and the second a PWR (pressurized water reactor)) were used for reference purposes as well as for validation purposes of the implemented model. The comparison between steady state simulations and the real plant data indicated a satisfactory accuracy of the model and of the thermodynamic approach used. Hataitep Wongsuwarn, [9], used thermodynamic properties of substance in numerical simulation and controller of industrial process. The Neuro fuzzy system (NFs) and subtractive clustering were used to calculate energy properties within the experimental steam power plant. Neurofuzzy models are constructed from each subsystem of thermodynamic properties, such as saturated water or superheat steams. Comparing experimental results of nonlinear Neurofuzzy model with several back propagation neural networks (BNNs), showed that the NFs modeling was closed to thermodynamic properties than neural network. Moreover, the proposed NFs model was used properly for the experimental steam power plant. Thus, the proposed NFs modeling should be applied to any plant based on using for thermodynamic properties. Leyzerovich and Alexander. S, [10], presented a study to improve the capacity of generating steam turbine. It was designed with the power arrived to (1000 MW) through the mechanical and thermal of re – design to increase the final stage for the low – cylinder pressure in the range of 1200 – 1500 mm in diameter. This study included methods to improve the efficiency of steam turbines and theoretically increase of the power through the increase of steam temperature for the superheat as well as increases the steam temperature of re – heating for the intermediate – pressure of inside the cylinder. This

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study were used a computer programs to simulate the expansion in the steam turbine, geometric dimensions, specifications steam, metals used …..ete. Cornell. Daniel et. al, [11], Presented the design method of the steam turbine up to the power of (758 MW) through the re – implementation of the high and medium design mechanically and thermally in the cylinder pressure by reducing the distance between the turbine stages. This study included improvement of flow factor, increasing the fixed and moving blades lengths, and increasing of annular space for the passage of steam through the stages. The study reported the development of certain types and specific models of steam turbines such as (model – D115) – Inc. (General Electric), which led to the work of very desirable balance between the costs, generated power through the turbine and the improvement of efficiency in turbine on the other hand. Behrooz Vahidi et. al, [12], published a paper for deriving the parameters of an IEEE governor – turbine model (particularly turbine model) based on a practical study case consisting of a 200 MW tandem compound, single reheat steam unit and its available heat balance data was presented. The main focus of this work was on presenting a regular procedure and using only available heat balance data of the steam unit, to be suitable for training the principles and details of such an approach for educational purposes. Unavailable parameters were approximated with simple thermodynamic assumptions, resulting in good correspondence to typical values. The model response to step changes for special scenarios was simulated and presented as well. Ali Chaibakhsh and Ali Ghaffari, [13], considered a steam turbine of a 440 MW power plant with once – through Benson boiler for the modeling approach. They characterized the transient dynamic of steam turbine, by developing a non – linear mathematical model firstly, based on the energy balance, thermodynamic principles and semi – empirical equations. Then, the related parameters of developed models were either determined by empirical relations or they were adjusted by applying Genetic Algorithm (GA). A nonlinear function was developed to evaluate specific enthalpy and specific entropy at the region when the flow deviates from perfect gas behavior, especially in the intermediate and low pressure stages. Comparison between the response of the turbine – generate – model with the response of real system validated accuracy of the improved model in steady state and transient conditions. The presented turbine– generator model can be used for control system design synthesis, performing real–time simulation desired states in order to have safe operation of a turbine – generator particularly during abnormal conditions such as turbine over – speed.

The main objectives of the present work to build up the theoretical model to simulate steam turbine power station. Use two analytical and simulation techniques that implicitly satisfy the traditional designer parameters and provide enough flexibility and accuracy to represent any steam turbine power plant. As well as Using the two packages Mat lap and Cycle – tempo to predict the optimal state of parameters that was used by turbine systems using genetic algorithms. The sources of exergy destruction were determined and categorized so that feasible recommendations could be made, moreover comparing the actual thermal efficiency of the power plant that can be obtained by applying the second law of thermodynamics.

THE SIMULATION MODEL

The modeling of steam turbine plant is built using firstly the techniques of Matlab version (V2013a with m– files Simulink and the second techniques is cycle – Tempo (Release 5) software Simulink to describe the thermodynamics , mass and heat balances for all component, at steady and unsteady (Transient) states. This program is used to Simulink the steam power plant with typical station of power 800MW capacity. The compatibles of steam power station type (K–800–23.5–0.0034). as well as the power plant of the Dura in Baghdad type (K–160–13.34–0.0068) is studied. The simulation model used to solve these two stations for steady state conditions using software Matlap and cycle – tempo programs, while unsteady state (transient case) using Matlap program only for the cases 60%, 80% and 100%. The Genetic Algorithm to tuning the PID (Proportional + Integral + Derivative) controller is built using m – file that drives the simulation of steam turbine model.

The simulation model can be capture in the term of mass and energy equation, semi – empirical equation and equation of state. There are many dynamic models for individual components, which are simple empirical relations between system variables with a limited number of parameters. In addition, an optimization approach based on genetic algorithm is performed to estimate the unknown parameters of models with more complex structure based on practical data. The models training process is performed by joining MATLAB Genetic Algorithm Toolbox and MATLAB Simulink and Cycle-tempo program.The power model consists of models of steam turbine, a control system, a generator and a power grid. To formulate components' models, unsteady conservation equations for a mass, energy

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and momentum have been used. In order to implement the model in Simulink and to maintain the amount of simulation time within the time available, some models were developed in both advanced and simplified versions. All models' components are connected through ports enabling and propagating current steam parameters (temperature, pressure…….etc.) and / or mass / energy flow rates.

High pressure steam turbine section

To build a model for the high – pressure cylinder included several steps, fig. (1): A relationship between mass flow and the pressure drop across the HP turbine was developed by Stodola formula [14];

$$G = K_1 \lambda \qquad (1)$$

Where, K_1 is a constant that can be obtained by the data taken from the turbine responses, and λ can be defined as formula;

$$\lambda = \sqrt{\frac{P_1^2 - P_{16}^2}{T_1}} \qquad (2)$$

by plotting λ via inlet mass flow rate based on the experimental data (taken from cycle – tempo prog.), the slop of linear fitting is captured as K_1=714.37 , is shown in fig.(2). Indicates the accuracy of the defined constant and $C_P = 1.697$.

$$\text{Then, } K_2 = \frac{C_P\,\eta_s^{HP}}{1000} \qquad (3)$$

The transfer function of the input and output pressure is;

$$\frac{P_{16}}{P_1} = \frac{S}{\tau s + 1} \qquad (4)$$

The input and output pressure relation for high presser cylinder based on experimental data (taken from cycle – tempo prog.), is shown in fig.(3). It shows a quite linear relation with the slope of S= 0.26101.

Where: time constant τ is determined by formula;

$$\tau = \frac{P_1}{G} V \frac{\partial \rho}{\partial P} \qquad (5)$$

Noting that the time constant for high pressure cylinder are normally between 0.1 and 0.4s, here the time constant chosen to be about 0.4s. By the dynamic model of high pressure turbine , the pressure, mass flow rate and temperature of steam at input and output of each section is required. The input and output relation for steam pressure and steam flow rate are defined in previous section. the steam temperature at turbine output (T_{16}) can be captured in the terms of entered steam pressure and temperature. By assuming that the steam expansion in high pressure turbine is an isentropic process , it is simple to estimate the steam temperature at discharge of HP turbine by using ideal gas pressure-temperature relation by formula;

$$\frac{T_{16}}{T_1} = \left(\frac{P_{16}}{P_1}\right)^{\left(\frac{n-1}{n}\right)} \qquad (6)$$

Then, find the out temperature (T_{16}) from last stage in high pressure turbine.

$$T_{16} = T_1 \left(\frac{P_{16}}{P_1}\right)^{\left(\frac{n-1}{n}\right)} \qquad (7)$$

Then we found the enthalpy and entropy , by using the thermodynamic property equations for steam (superheated and saturated) . The energy equation for adiabatic expansion , which relates the power output to steam energy declining by passing through the high pressure turbine, determine by formula;

$$W_{HP} = \eta^{HP} G (h_1 - h_2) = \eta^{HP} C_p G \quad (T_1 - T_2) \quad (8)$$

Then ,

$$W_{HP} = \eta^{HP} C_p G \quad \left(T_1 - T_1 \left(\frac{P_2}{P_1}\right)^{\left(\frac{k-1}{k}\right)}\right) =$$
$$\eta^{HP} C_p G \quad (T_1 + 273.15)\ ` \ (9)$$

And find the mass flow rate at any stage in high pressure cylinder by using heat and mass balance

Intermediate and low – pressure turbine section

The intermediate and low-pressure turbines have more complicated structure in where multiple extractions are employed in order to increase the thermal efficiency of turbine. The steam pressure consecutively drops across the turbine stages. The condensation effect and steam conditions at extraction stages have considerable influences on the turbine performance and generated power. In this case, developing mathematical models, which are capable to evaluate the released energy from steam expansion in turbine stages, is recommended. The steam thermodynamic properties can be estimated in term of temperature and pressure as two independent variables. A variety of functions to give approximations of steam/water properties is presented, which are widely used in steam power plant applications. To build a model for the I – pressure cylinder included several steps. Find the thermodynamic properties of steam and water (enthalpy, liquid phase h_f , enthalpy, vapor phase h_g , enthalpy, tow- phase h_{fg} , entropy, liquid phase s_f , enthalpy and vapor phase h_g) . The relation between the input mass flow rate from reheated to I – P cylinder and the mass flow rate at all extraction based on experimental data (using cycle- tempo program) .It shows a quite linear relation with the slope at (extraction.3 and extraction .5) of (S_3= 0.024727 & S_5=0.03602).

The transfer function of the input and output mass is;

$$\frac{\dot{m}_{ex}}{G_{IP}} = \frac{S}{\tau s + 1} \qquad (10)$$

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Where, G_{IP} is the mass flow rate inlet the intermediate pressure cylinder, The time response of the transfer function.

By considering steam expansion at turbine stages be an ideal process, the energy equations for steam expansion in turbine, which relates the power output to steam energy declining across turbine stages can be captured. Therefore, the work done in IP turbine can be captured as follows;

$$W_{iP} = G_{IP}(h_4 - h_{ex18}) + (G_{IP} - \dot{m}_{ex19})(h_{ex18} - h_{ex19}) + (G_{IP} - \dot{m}_{ex18} - \dot{m}_{ex19})(h_{ex19} - h_{ex23}) + (G_{IP} - \dot{m}_{ex18} - \dot{m}_{ex19} - \dot{m}_{ex23})(h_{ex23} - h_{ex24}) \quad (11)$$

Then, the power for IP turbine determine by formula;

$$W_{IP} = \eta_s^{IPC} W_{iP} \quad (12)$$

Finally the mass flow rate at any stage in intermediate pressure cylinder by used heat and mass balance. To build a model for the L – pressure cylinder included several steps. The relation between the input mass flow rate I – P to L – P cylinder and the mass flow rate at all extraction based on experimental data (using cycle – tempo program) ,which shows a quite linear relation with the slope at (extractuin.7 and extractuin.8) of (S_7= 0.06254 & S_8= 0.040443). The transfer function of the input and output mass is;

$$\frac{\dot{m}_{ex}}{G_{LP}} = \frac{S}{\tau s+1} \quad (13)$$

Now, the low-pressure turbine consists of two extraction levels. The work done in LP turbine can be captured as follows;

$$W_{lP} = G_{LP}(h_{25} - h_{ex25}) + (G_{LP} - \dot{m}_{ex25})(h_{ex25} - h_{ex26}) \quad (14)$$

Where, G_{lP} is the mass flow rate inlet the low pressure cylinder.

Then, the power for LP turbine determine by formula;

$$W_{LP} = \eta_s^{LPC} W_{lP} \quad (15)$$

Then the overall generated mechanical power (P_m) can be captured by summation power in turbine stages determine by formula;

$$P_m = W_{HP} + W_{IP} + W_{LP} \quad (16)$$

TURBINE PERFORMANCE UNDER TRANSIENT CONDITIONS

The model performs initially steady state analysis, based on input specifications defined by the user like power output or initial steam and condensing pressures, and more specific parameters regarding either power block or boiler and turbine efficiency, which can be set according to default values or modified voluntarily. The result is summarized by the heat and mass balance of both power block and steam generator at rated operation. New stable results are calculated according to the heat input and on the variable load at transient condition. In practical at load variations, both mass flow rate pressures are expected to decrease simultaneously. During operation, a turbine may run an appreciably long time with varying steam flow rate in start – up and shut – down regimes, often with substantial deviations of the initial and final steam parameters from the rated values. The rated conditions can also be disturbed owing to salt deposition in the steam path or when a turbine is run with some blades in turbine stages having been removed or when the geometry of blade cascades has been distorted due to cross flexure of blade edges. In order to estimate property, the variations in the efficiency and reliability of the operation of a turbine and its stages under transient conditions, i.e. deviating strength calculations for these off – design conditions [15]. Transient performance is calculated in an iterative resolution of steam generator and steam turbine models, since they are interrelated through the thermodynamic properties of live steam calculated with the Matlab and tempo – cycle program. For transient condition, the extraction pressure and inlet pressure to each turbine section is calculated using Stodola's Cone law as follow [16];

$$\frac{\dot{m}}{\dot{m}_0} = \frac{P_a}{P_{a,0}}\sqrt{\frac{P_{a,0}\,v_{a,0}}{P_a\,v_a}}\sqrt{\frac{1-\left(\frac{P_b}{P_a}\right)^{\frac{n+1}{n}}}{1-\left(\frac{P_{b,0}}{P_{a,0}}\right)^{\frac{n+1}{n}}}} \quad (17)$$

Where: (P) the pressure and (v) the specific volume. The sub index (a) stands for the inlet value, (b) for the outlet value and (0) for the design values, and n for wet steam the calculation of the polytrophic exponent is (Traupal)[17];

$$n = \frac{k}{1+\frac{kP(v_{steam}-v_{liquid})}{h_{fg}}(1-\eta_T)} \quad (18)$$

Where: η_T the overall efficiency of the turbine.

REHEATER MODEL

The superheated steam from main steam header is fed toward the high pressure turbine , and from high pressure turbine is discharged into the cold reheat header. The steam temperature in cold reheat line is (304°C). The outlet reheated steam temperature should be constant 540°C , at the full load condition; the outlet reheated steam pressure is 3.42MPa. the reheated dynamics increase nonlinearity and time delay of the turbine and should take into account as a part of turbine model. The parameters of this

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model are determined either from construction data such as fuel and water steam specification. We have developed accurate mathematical model for subsystems of boiler based on the thermodynamics principles and energy balance. The equation for the superheated temperature model is as follows;

$$\frac{dT_4}{dt} = K_2(K_1\dot{m}_{fuel} + \dot{m}_2(T_2 - T_4 + B_1) + B_2) \quad \ldots\ldots\ldots\ldots (19)$$

Where: $K_1 = H_v C_P$, $K_2 = \frac{1}{\rho_s V_s}$, $B_1 = \frac{k_1}{C_P}$, $B_2 = k_0 \rho_s V_s$

The heat flow can be captured by using calorific value, lower heating value (H_v) of the fuel and the temperature output from the high pressure turbine (T_2) , the temperature output from the reheater (T_4) , the mass flow input to reheater ($\dot{m}_2$). In this model the steam quality has significant effects on output temperature and should be considered in related equations. The transfer function for fuel flow rate and steam quality is as follows;

$$\frac{\alpha}{\dot{m}_{fuel}} = \frac{9.45039e-6}{20s+1} \qquad (20)$$

GENERATOR MODEL

The turbine – generator speed is described by the equation of motion of the machine rotor , which relates the system inertia to deference of the mechanical and electrical torque on the rotor.

Applying the swing equation of asynchronous machine to small perturbation, we have;

$$M\frac{d^2\delta}{dt^2} = P_a = P_m - P_e \quad (MW) \qquad (21)$$

Where: M is called inertia constant, and δ is torque angle or swing angle , P_a is acceleration power (MW) , P_m is mechanical power input in (MW) and P_e electrical power output in (MW) .

$P_{max} = \frac{EV}{X}$ (S.S.S limit) (Steady state stability limit) ………... (22)

Then;

$$P_e = P_{max} \sin\delta = \frac{EV}{X} \sin\delta \qquad (23)$$

The electrical power can be captured in term of terminal voltage (V), machine excitation voltage (E), direct axis synchronous reactance (X) .

Where; $M = \frac{GH}{\pi f}$ b(24)

Then the equation (19) can write for the system operating frequency electric $f(H)$;

$$\frac{GH}{\pi f}\frac{d^2\delta}{dt^2} = P_a = P_m - P_e \quad MW \qquad (25)$$

Dividing throughout by (G) machine rating (base) in MVA.

$\frac{H}{\pi f}\frac{d^2\delta}{dt^2} = P_a = P_m - P_e$ In pu (δ it is measured by radian) (26)

$\frac{H}{180f}\frac{d^2\delta}{dt^2} = P_a = P_m - P_e$ In pu (δ it is measured by degree) (27)

COMPUTER PROGRAM

To describe the performance of each study, a computer program has been written to work under Mat lab software and compared with the cycle – tempo software. The program enables at each node through the thermodynamic cycle by using the appropriate thermodynamic relations. And build the Simulink and model by use the two programs for the steam turbine at steady state and transient with change the load and taken the GA at power, pressure and mass rate. A flow – sheet computer program, “Cycle – Tempo” is used for the study. The selected case study is Russia power station (K–800–23.5–0.034) and Dura type (K–160–13.34–0.0068) steam power plant located in Baghdad, Iraq. The superheated steam enters the two – stage single reheat steam turbine at 22.3MPa, 560℃, 640Kg/s and 3.51MPa, 530℃ , for high and intermediate pressure stages, respectively. Steam enters the low pressure stage with a pressure of 6.934 bar; the condenser pressure is 0.034MPa. The simulation process and the most important parameters are described in this section. The parameters can be changed to build and simulate different cases and a flow-sheet computer program, “Cycle – Tempo” (Cycle – Tempo – Release 5), is used for that purpose. It is a well – structured package for steady state thermodynamic modeling and analysis of systems for the production of electricity, heat and refrigeration.

RESULTS AND DISCUSSION

Figure (4) indicated thermal efficiency of the cycle versus steam pressure at turbine inlet temperature for Russia power station (K – 800 – 23.5–0.0034). Thermal efficiency increases with increases steam pressure at turbine and inlet temperature. As well as thermal efficiency increases with increases steam temperature. Figure (5) reveal thermal efficiency versus steam temperature at turbine inlet temperature for Russia power station (K – 800 – 23.5–0.0034). The efficiency of the cycle increases with increase steam temperature as well as increases with increases steam pressure. The internal exergy efficiencies of the power cycles are depicted in figure (6) for the single reheat systems. The internal exergy efficiencies are primarily determined by the isentropic efficiencies of the steam turbine. In general these isentropic efficiencies are higher as the steam volume flow rate is higher. The internal efficiencies of the single reheat systems are in full agreement with this rule. The internal exergy efficiencies of the power cycles are higher if the steam

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temperature is higher, and are lower if the steam pressure is higher. Figure (7) depicted the reversible efficiency versus steam temperature for Russia power station (K – 800 – 23.5–0.0034). The reversible efficiency as well as increases with steam pressure. Figure (8) show the response of the turbine – generator for Russia power station (K – 800 – 23.5–0.0034). The load responses in steady state and transient conditions over an operation range between 50% and 100% of nominal load. This figure indicated the behavior of the turbine – generator system. Figure (9) illustrated the response and pressure model at high pressure turbine and Russia power station (K – 800 – 23.5–0.0034). This figure indicated that the time responses of the proposed transfer function. As well as a good agreement between real and model. Figures (10), (11) and (12) reveal the response of pressure – mass model to H.P.T, I.P.T and L.P.T to Russia power station (K – 800 – 23.5–0.0034). As it is clearly seen, the results indicated a good agreement between real and pressure – mass model data. Figures (13), (14) and (15) indicated convectional water – steam cycle for Russia power station (K – 800 – 23.5 – 0.0034). The design calculations were three loads and power 100%, 800 MW, 90%, 720MW and 80%, 640MW respectively. These calculations were by using cycle – tempo program. Figures (16), (17) and (18) reveal convectional water – steam cycle for Dura power station (K – 160 – 13.34 – 0.0068). The design calculations were three loads and power 100%, 160MW, 90%, 144MW and 80% and 128MW. These calculations were by using cycle – temperature program. When using two program software cycle – tempo and Mat lab gave the same results in simulation of power plant. The results indicated that the extraction pressure increases with increases inlet pressure of I.P.T. as well as the extraction exergy increases with increases inlet exergy of H.P.T and I.P.T. The reversible efficiency increases with increases steam temperature as well as increases with steam pressure.

CONCLUSION

The conclusions can be drawn from the results of theoretical study were as follows:

1. In this study were using two model pressure – mass flow model and pressure model.
2. The pressure drop across the turbine stages are approximately linear and can be defined by the first order transfer function
3. The response of pressure model at high pressure turbine indicated that the time responses of the proposed transfer function.
4. Inlet pressure increases with increases overall power the relation between them linear relation.
5. The inlet exergy increases with increases power.
6. The extraction mass increases with increases mass flow rate of I. P.T.
7. The efficiency of the cycle increases with increases steam temperature and steam pressure.
8. The internal exergy efficiencies of the power cycle are higher if the steam temperature is higher, and are lower if the steam pressure is higher.

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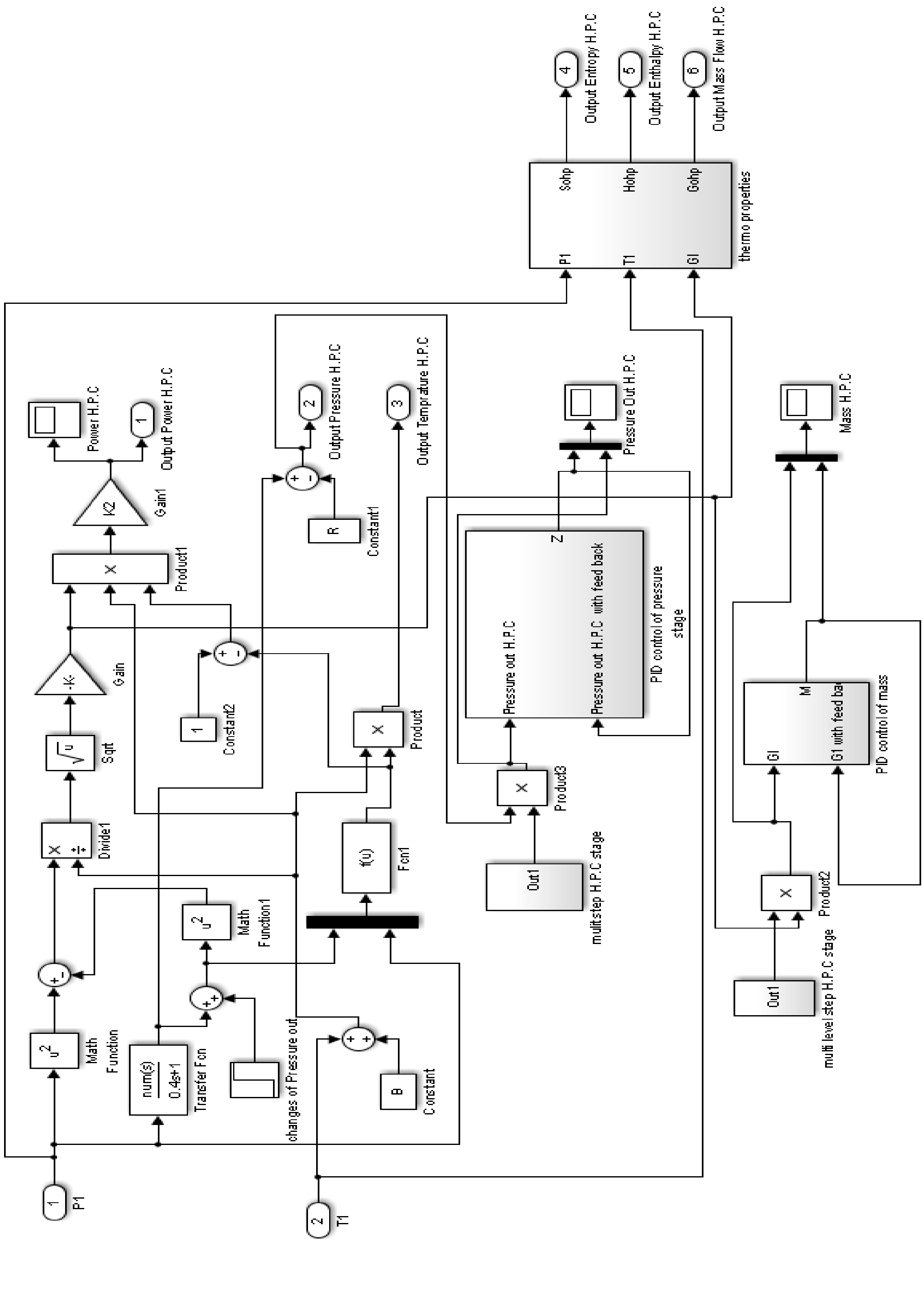

Fig.(1).High pressure turbine model.

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λ

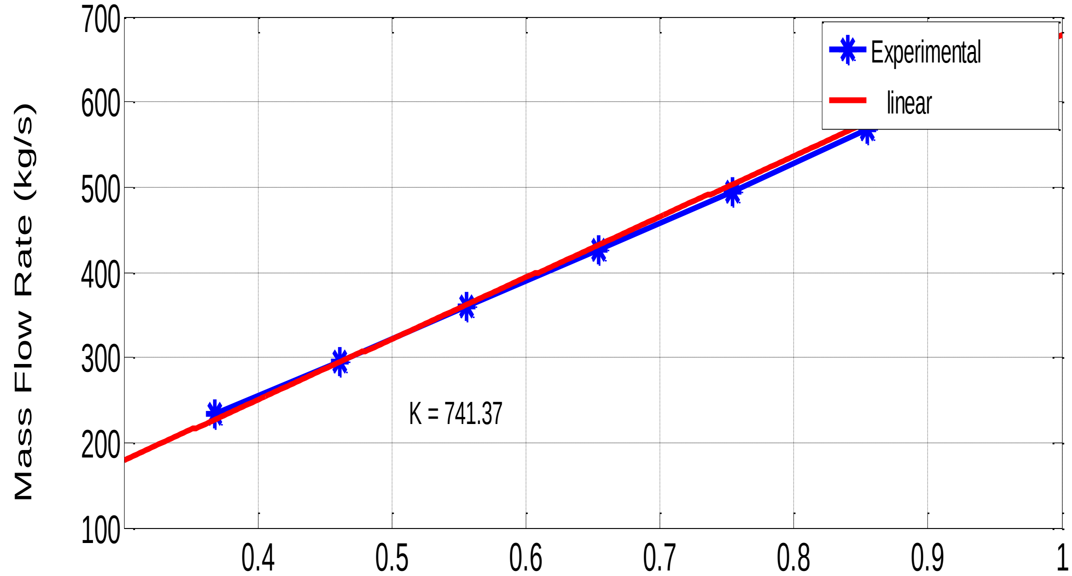

Fig.(2).Mass flow rate versos λ for Russia power station (K – 800 – 23.5 – 0.0034).

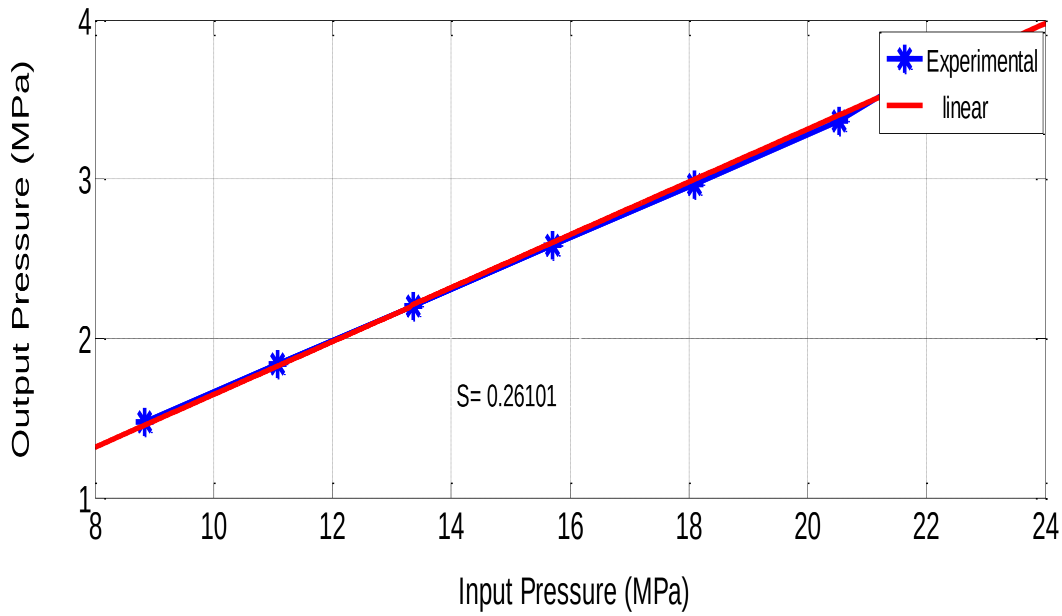

Fig.(3).Pressure ratio of the high pressure turbine cylinder input and output for Russia power station (K – 800 – 23.5 – 0.0034).

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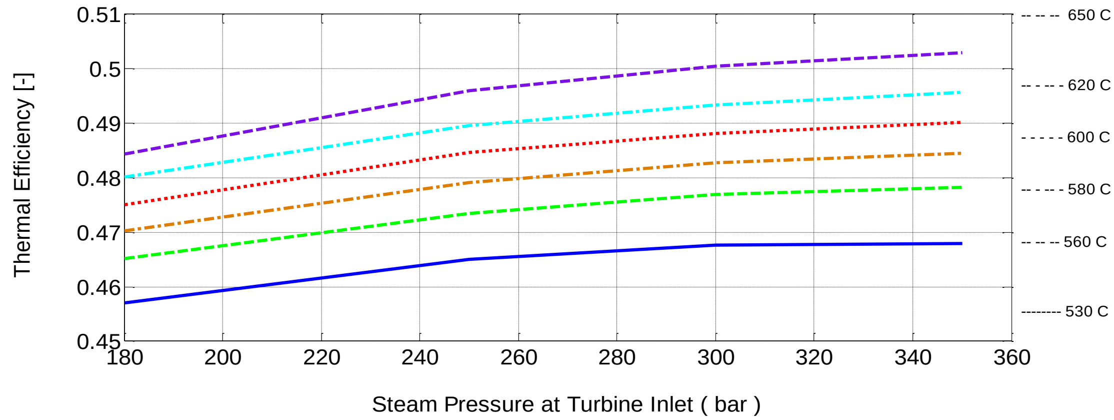

Fig.(4) Cycle efficiency versus steam pressure at turbine inlet temperature for Russia station (K – 800 – 23.5–0.0034).

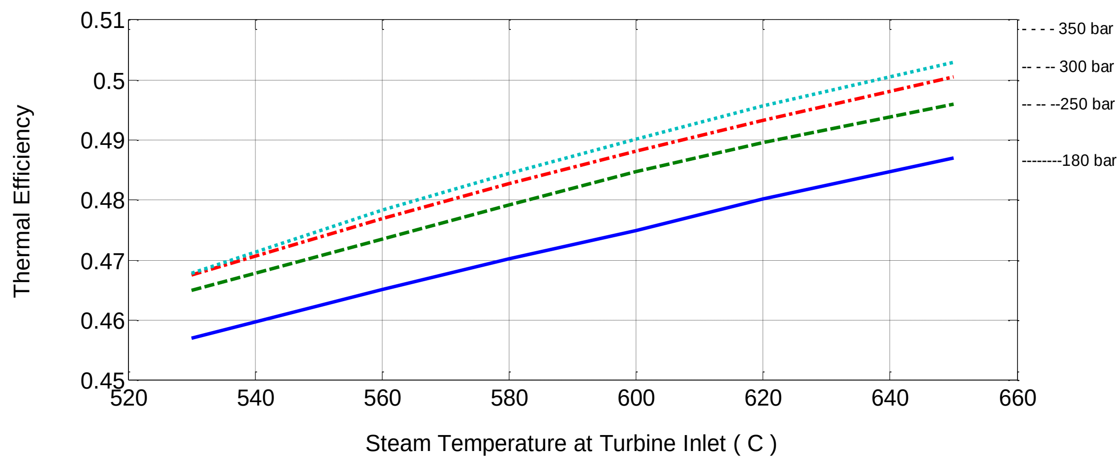

Fig.(5) Cycle efficiency versus steam temperature at turbine inlet temperature, for Russia station (K – 800 – 23.5–0.0034).

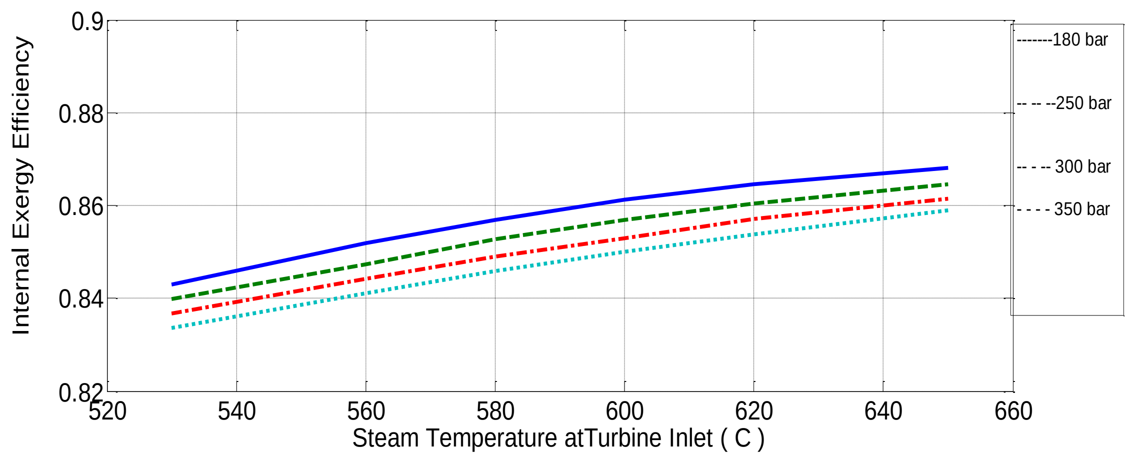

Fig.(6) The internal exergy efficiency versus steam temperature (single reheat) for Russia power station (K – 800 – 23.5–0.0034).

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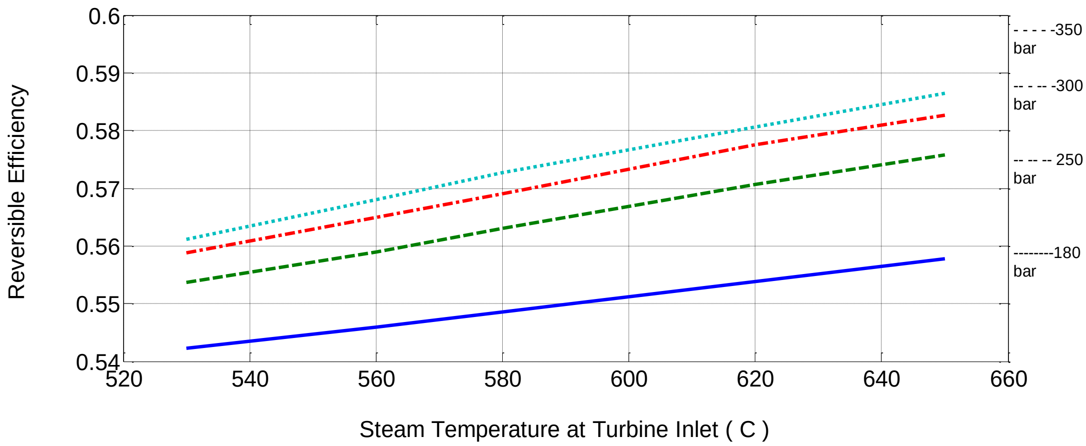

Fig.(7) The reversible efficiency versus steam temperature at turbine inlet for Russia power station (K – 800 – 23.5–0.0034)

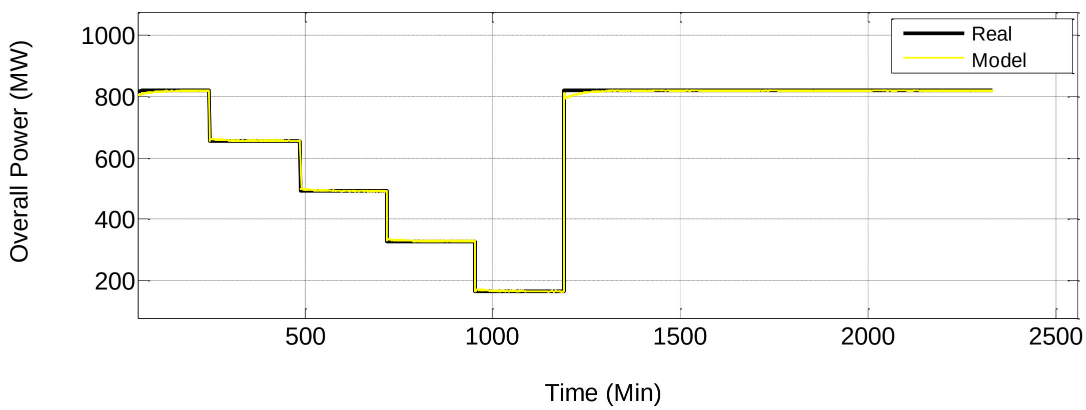

Fig.(8).Response of the turbine – generator for Russia power station (K – 800 – 23.5–0.0034).

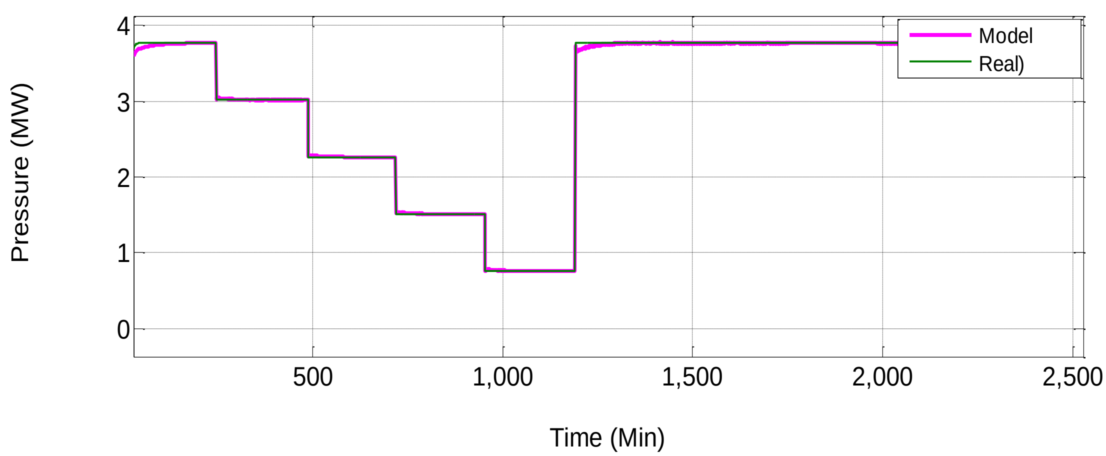

Fig.(9).Response of pressure model at H.P.T for Russia power station (K – 800 – 23.5–0.0034).

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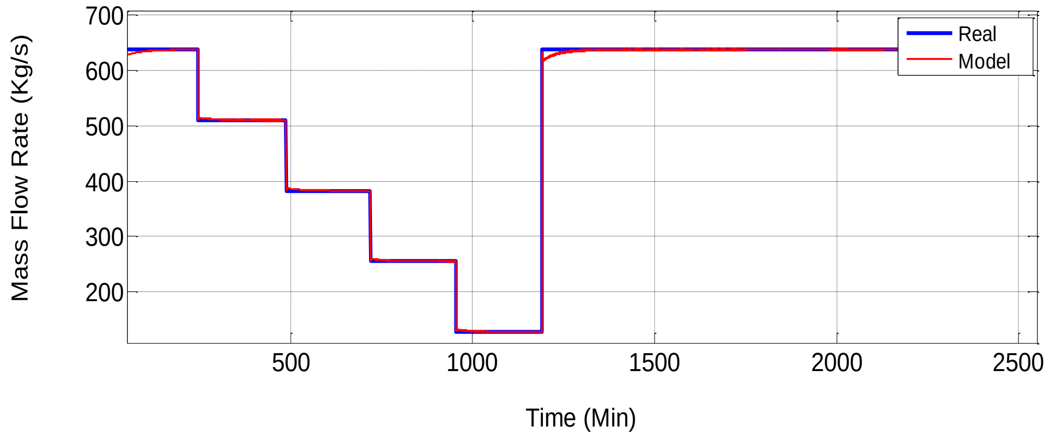

Fig.(10).Response of pressure–mass flow model at H.P.T for Russia power station (K – 800 – 23.5–0.0034)

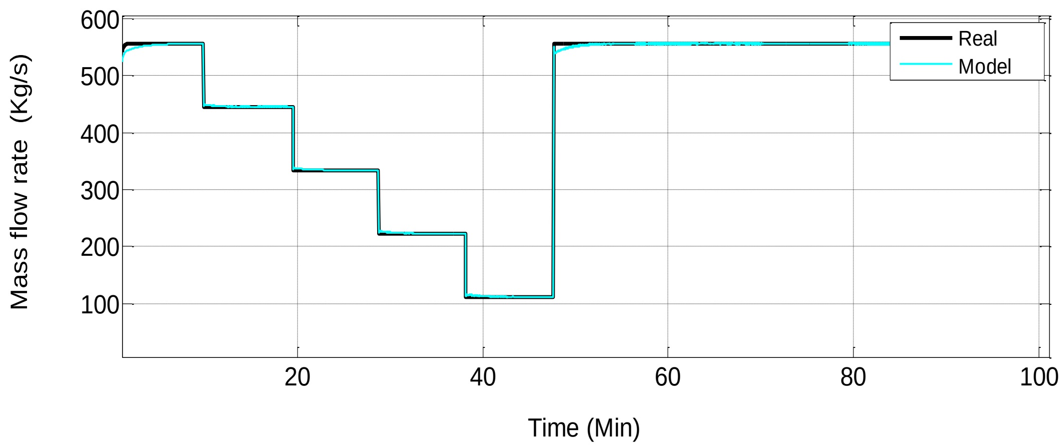

Fig.(11).Response of pressure – mass flow model at I.P.T for Russia power station (K – 800 – 23.5 – 0.0034)

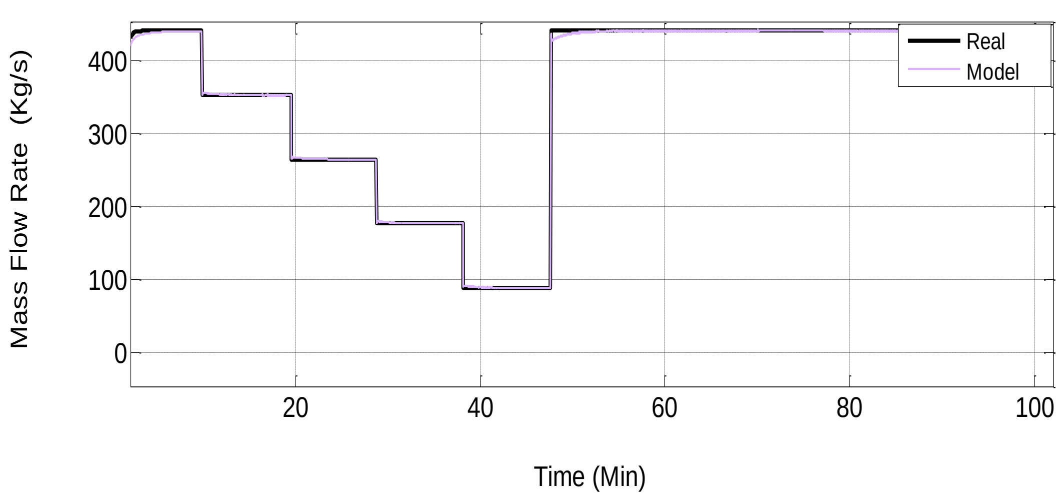

Fig.(12).Response of pressure – mass flow model at L.P.T for Russia power station (K – 800 – 23.5–0.0034).

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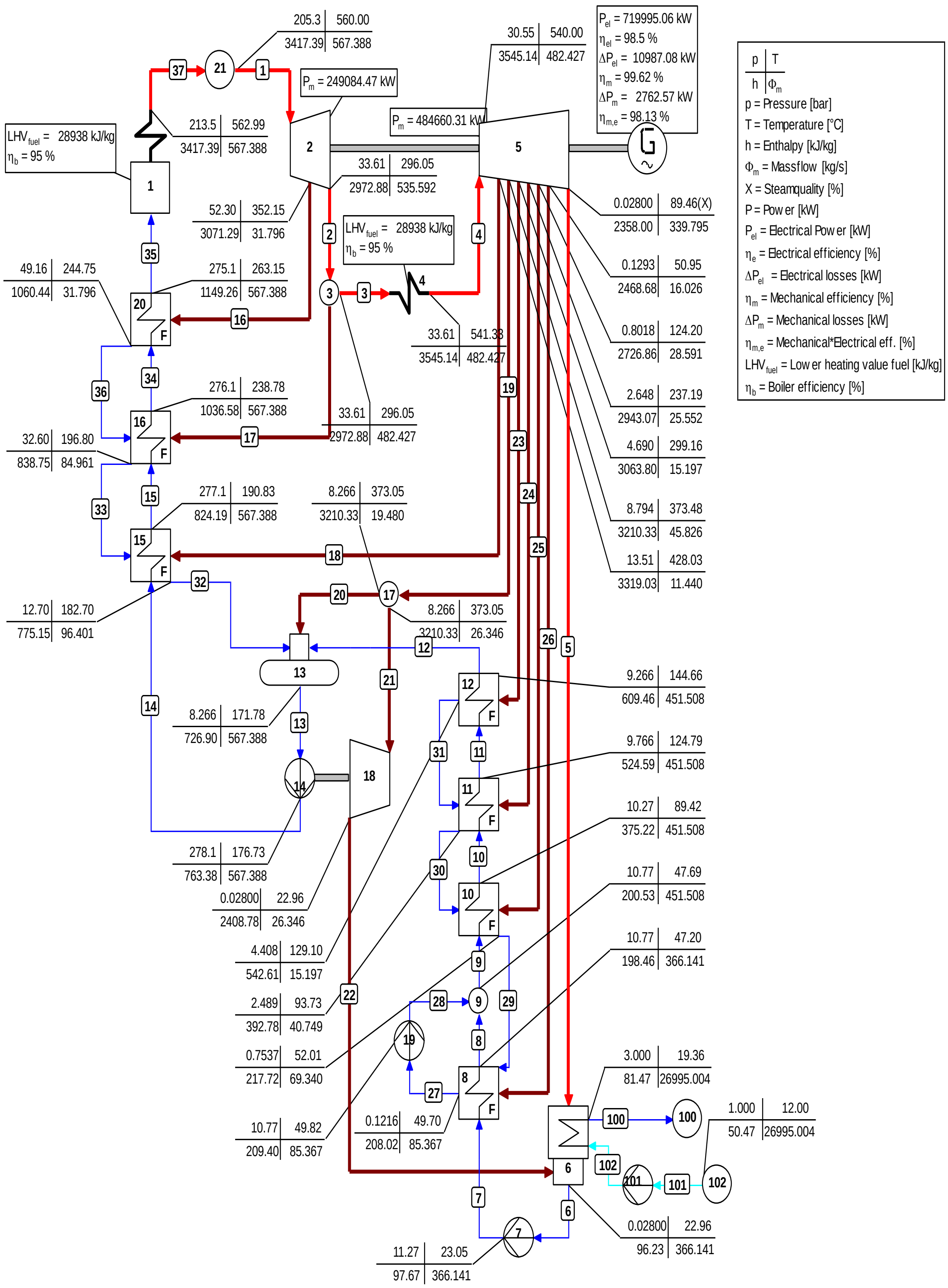

Fig.(13).Convectional water – steam cycle at Russia power station, design calculation at 100% load and power 800MW

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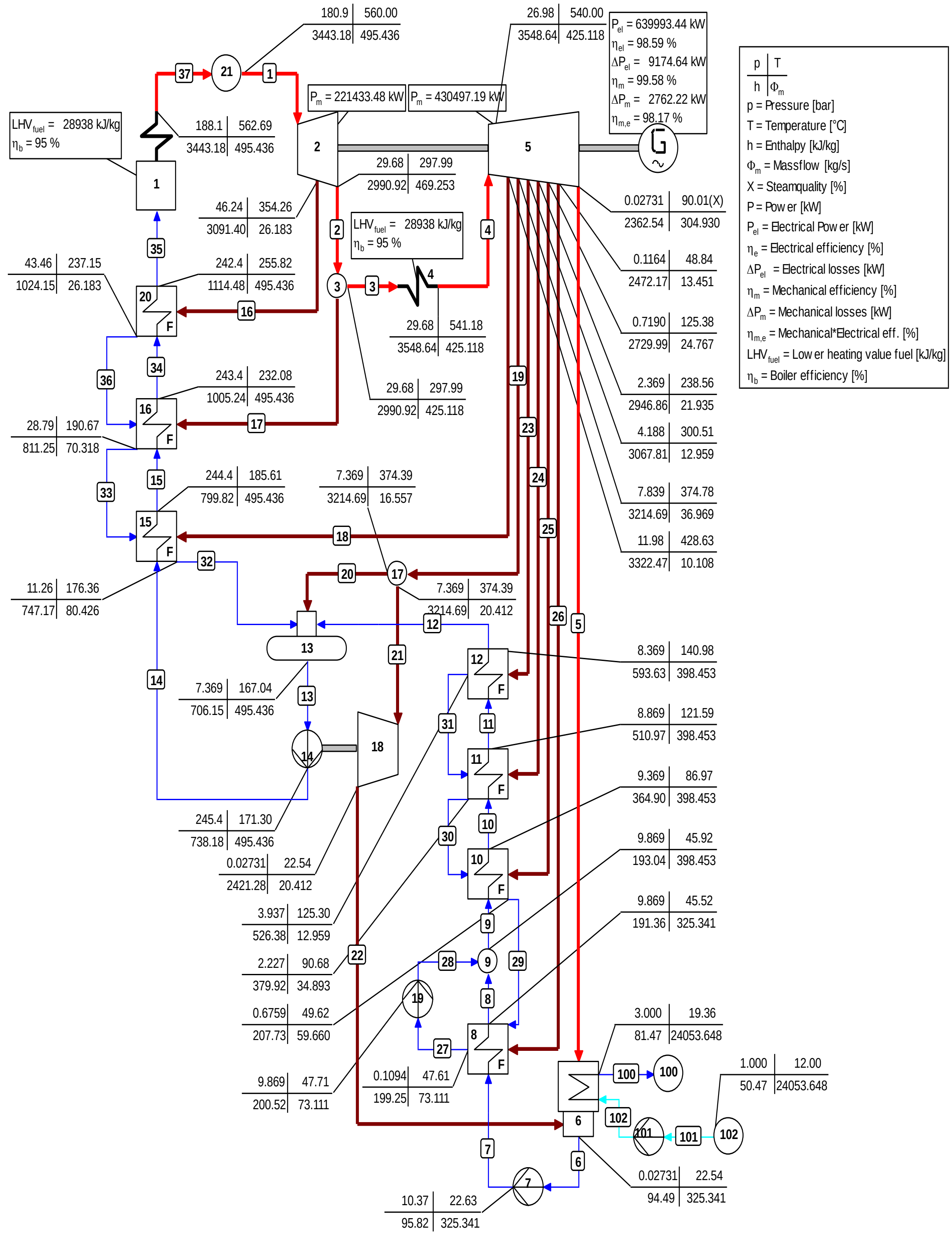

Fig.(14).Convectional water – steam cycle at Russia power station, design calculation at 90% load and power 720 MW

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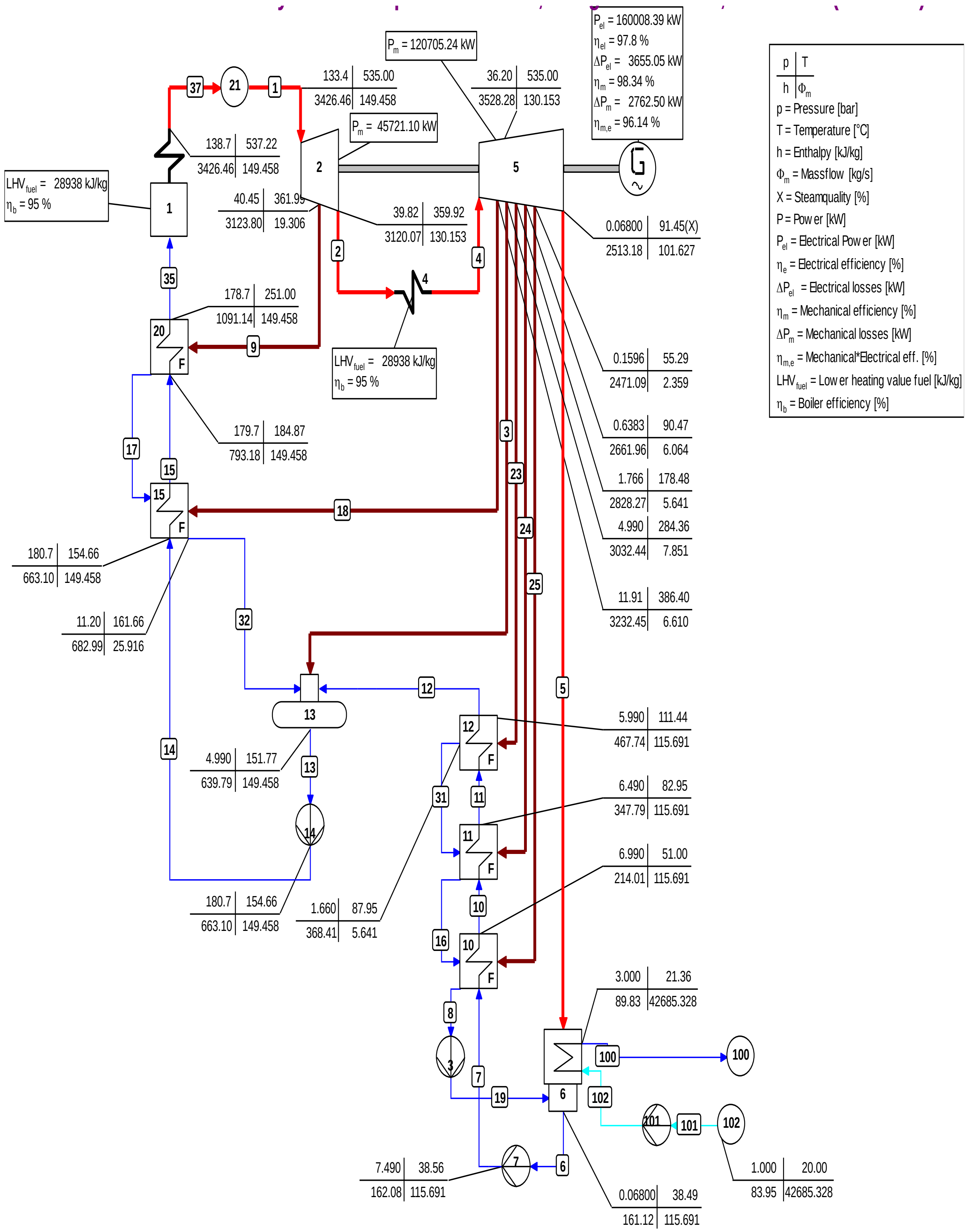

Fig.(15).Convectional water – steam cycle at Russia power station, design calculation at 80% load and power 640 MW

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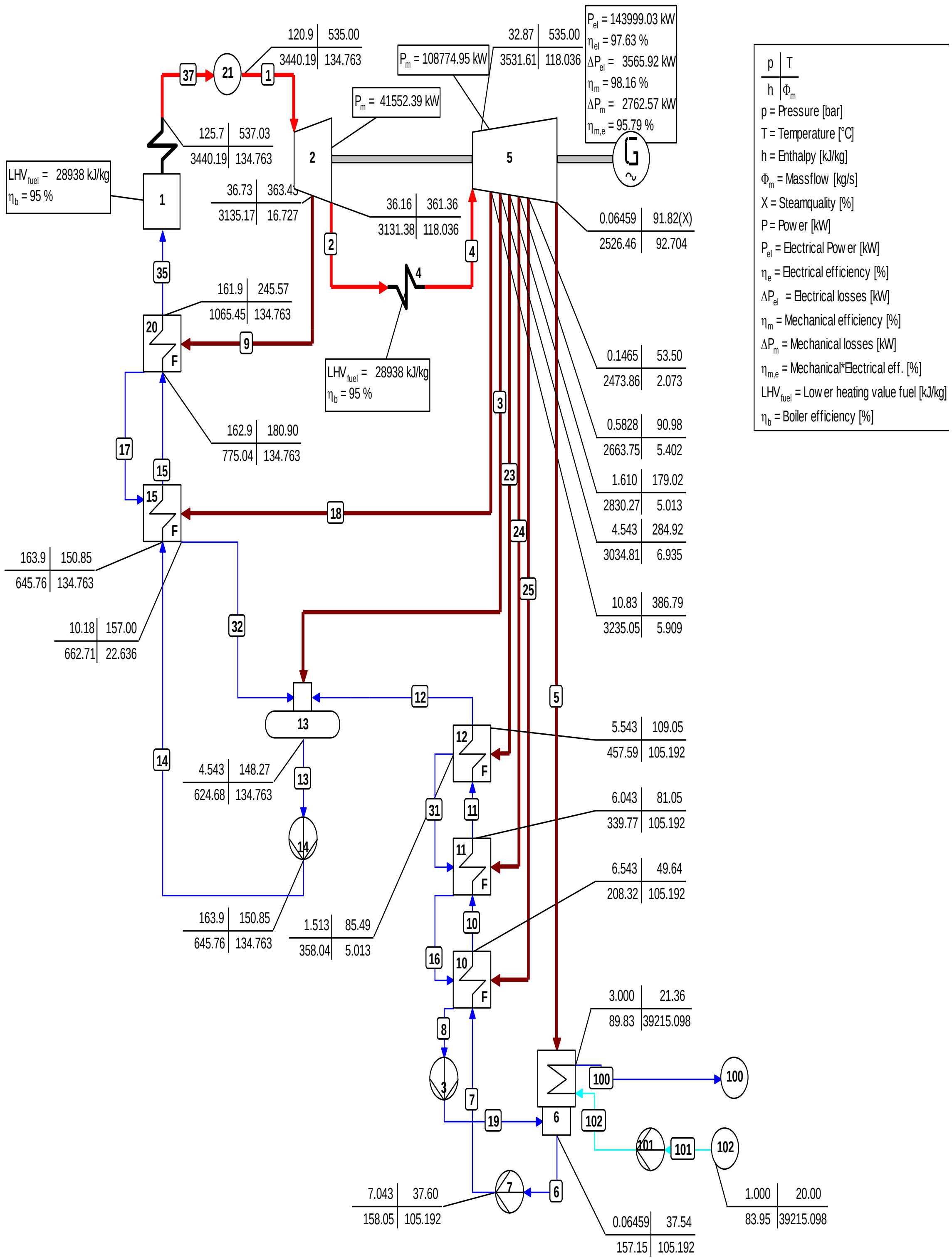

Fig.(16).Convectional water – steam cycle at Dura power station, design calculation at 100% load and power 160 MW

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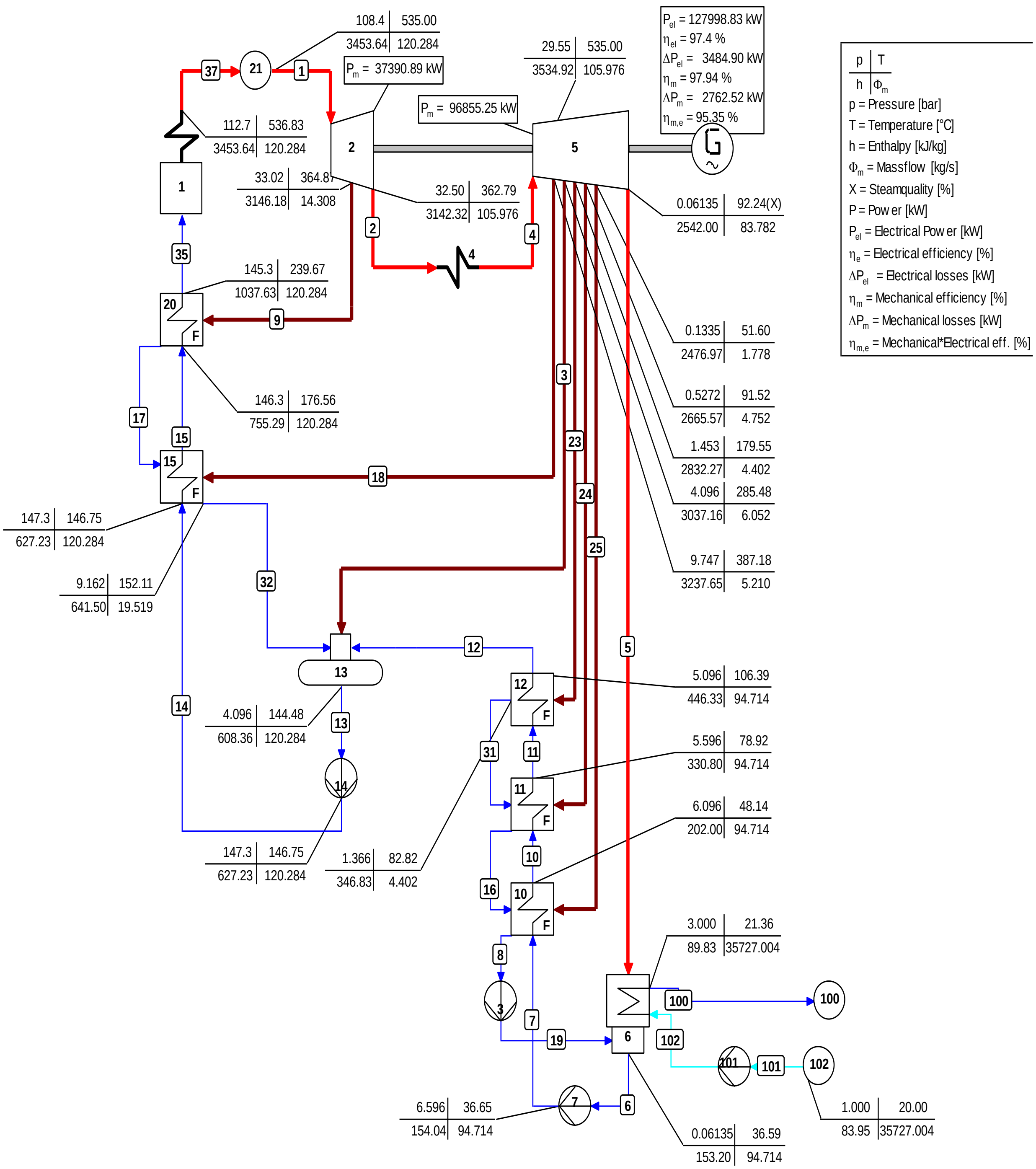

Fig.(17).Convectional water – steam cycle at Dura power station, design calculation at 90% load and power 144 MW

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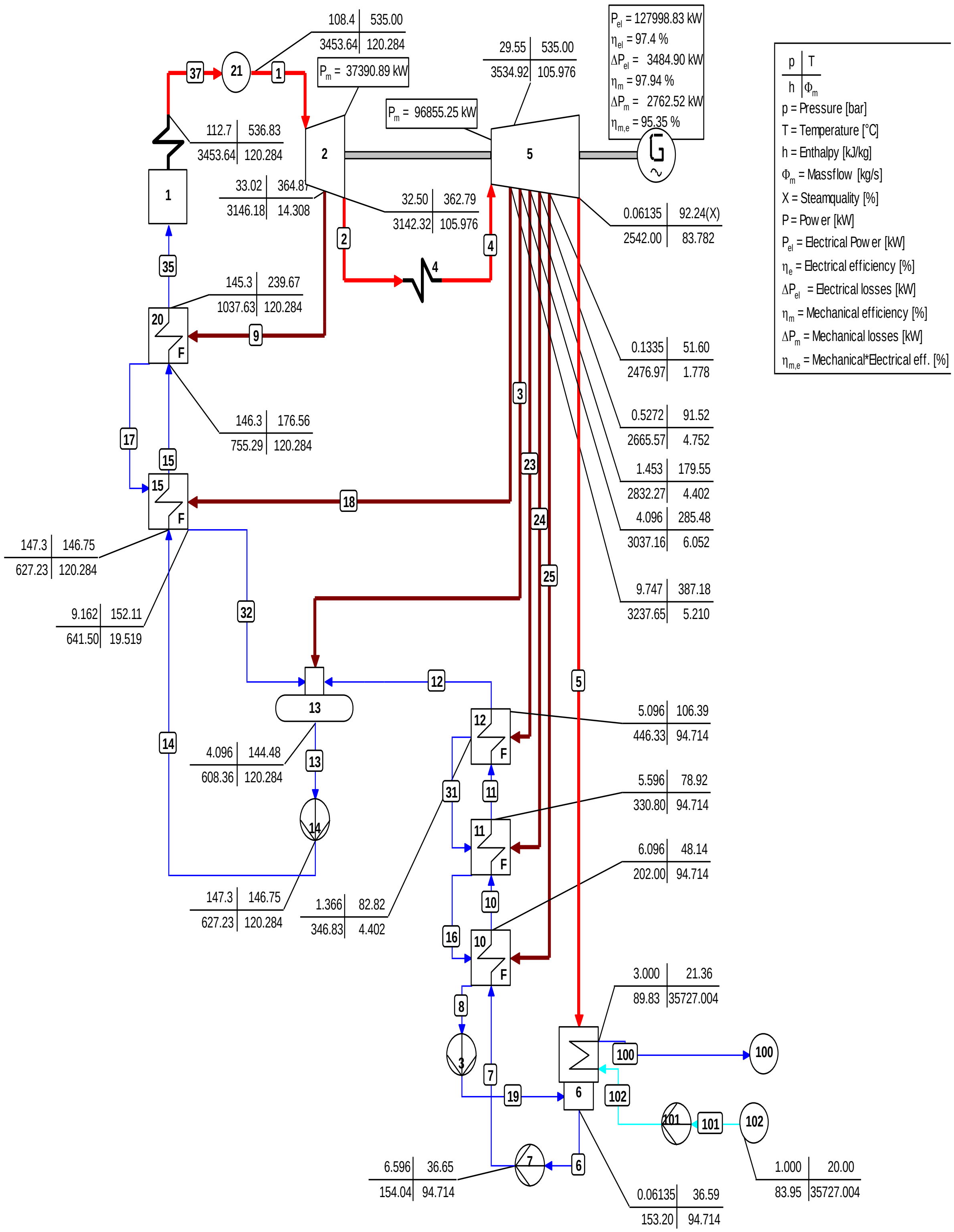

Fig.(18).Convectional water – steam cycle at Dura power station, design calculation at 80% load and power 128 MW

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NOMENCLATURE

A, B C,D,E	Constant in equation	–
T	Temperature	ºC
G	Inlet mass flow rate	Kg/s
M	Extraction mass	Kg/s
S	Entropy	kJ/kg.k
H	Enthalpy	kJ/kg
h_0	Enthalpy of main steam	kJ/kg
V	specific volume	m^3/kg
h_{rh}	Enthalpy of reheater	kJ/kg
h'_c	Enthalpy of condensate (in the ideal Rankine cycle)	kJ/kg
h_{ext}	Enthalpy of extraction	kJ/kg
G_c	steam flow rate to the condenser	Kg/s
$\dot{m}_{ex}$	Mass flow rate at extraction	Kg/s
W_{IP}	Power for IP turbine	MW
W_{iP}	work done in IP turbine	MW
E	Machine excitation voltage	(V)
W_{LP}	Power for LP turbine	MW
W_{lP}	Work done in LP turbine	MW
W_{HP}	Power for HP turbine	MW
P	Pressure	MPa
P_0	Ambient pressure	bar
T_0	Temperature of the environment	ºC
T_{og}	Fuel gas temperature	ºC
T_{in}	Inlet temperature	K
P_c	Final pressure of steam at condenser	MPa
Q_B	Heat added to the boiler	kJ/kg
$Q_{rh.}$	Heat added to the reheater	kJ/kg
ρ	Specific density	Kg/m^3
ρ_s	Density of steam	Kg/m^3
X_C	Steam quality	%
V_s	Specific volume of steam	m^3/ Kg
V	Terminal voltage	(V)
N_{el}	Nominal electrical power for steam turbine plant	MW
N_{ef}	Effective power	MW
N_i	Internal power	MW
d_z	Diameter	m
l_{2z}	Height of moving blades	m
Ω	Axial surface area	m^2
$\dot{m}_{fuel}$	Mass of fuel	Kg/s
m_g	Mass of gas	Kg/s
c_{Pg}	Specific heat at constant pressure of gas	kJ/kg.k
m_s	Mass of steam	Kg/s
m_w	Mass of water	Kg/s
c_{Pw}	Specific heat at constant pressure of water	kJ/kg.k
I_{ofwh}	Irreversibility of open Feed water heater	kJ
I_{fwhc}	Irreversibility of closed Feed water heater	kJ
E_s	Exergy of steam	kJ
X	direct axis synchronous reactance	(X)
M	inertia constant	Kg.m^2/s
δ	rotor angle	(rad)
τ	time constant	(s)

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n	polytrophic exponent	–