DEVELOP A STANDARD START-UP PROCEDURE OF STEAM TURBINE IN A POWER PLANT

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ABSTRACT

Start-up procedure of a turbine depends on its casing and rotor temperature, pressure of steam etc. There are a variety of factors contributing to the improvement of the quality and security of this process. Therefore, in this study an analysis on of a specific case in a thermal power plant in Vietnam has been done.

Keyword: *Thermal power plant, loading, steam turbine, high pressure (HP, intermediate pressure (IP), low pressure (LP), turbine start-up, operating parameters. etc..*

1. INTRODUCTION

In thermal power plants, turbines work at high pressure, so it requires a very careful technological process as well as a meticulous operation process, otherwise there will be huge consequences leading to damage or even shutdown of the plant for a long time.
It is imperative requirement that there is a uniform heating and expansion of turbine to avoid the permanent deformation of turbine rotor or any other catastrophic failure. It is something that any steam turbine manufacturer as well as supplier requires in different ways.

2. STARTING UP PROCESS OF STEAM TUBINE TYPE N57,5 -8,83/535 IN THERMAL POWER PLANT

The turbine of the thermal power plant we consider is type N57,5-8.83/535 which is a high-pressure, single-body, single-axis that manufactured by Harbin Turbine Company. The rated capacity of the turbine is 57.5 MW

Fig -1: Harbin sub-critical steam Turbine

The rotor has a structure consisting of shaft, disc and blades, HP and IP turbines are forged monolithically, the LP turbine is coupled, the blades are connected to the rotor in a direction perpendicular to the axis through the disc to reduce the collective stress. The blade material is 30CrNi4MoV that is heat-resistant alloy steel. The end of the turbine rotor shaft is connected to the generator rotor shaft by a coupling, the coupling material is 30CrNi3Mo.

There are some steam turbine specifications as below:

Table 1- Steam turbine type N57,5 -8,83/535 TYPE specifications

Parameter name	value
Rated speed	3000 rpm
Rated power	57.5 MW
Maximum power	64 MW
Fresh steam pressure	8.83 $^{+}/^{-}$ 0,49 MPa
Fresh steam temperature	535 $^{+}/^{-}$ 5 ^{o}C
Rated consumption steam load	208,5 t/h
Temperature of circulating cooling water (rated/max)	30/ 33 ^{o}C
Feed water temperature	216,5 ^{o}C
Steam consumption rate	3,626 kg/ kW.h
Heat dissipation rate	9251 kJ/ kW
Outflow steam	159 t/h
Pressure in condenser	0,0082 MPa

2.1. Operating the sub-equipment and sub-systems of the turbine before its starting-up process.

Before starting the turbine, the following sub-systems and and sub-equipment should be set into operation in accordance with the sequence outlined in the turbine start-up procedure documentation of plant such as:

- Operating a closed circulating cooling water system;
- Operate industrial pumps;
- Operate self-contained steam system;
- Operating the circulating water system,
- Operate the water supply system,
- Operate condensate system,
- Operating an open circulating water system,
- Operate the oil steam extraction system,
- Lubrication system operation

2.2. Start-up the turbine process.

Starting the unit has 3 states: Cold, warm and hot status. The start-up state of the unit is based on the turbine temperature. It also depends on its casing and rotor temperature. As the turbine is subjected to high temperature and pressure for long time, it is mandatory requirement that there is a uniform heating and expansion of turbine. Otherwise due to uneven heating, uneven expansion will occur which can finally lead to either permanent deformation of turbine rotor or any other big failure. All these 3 methods of turbine start-up states have the same the order of execution but the start - up parameters are different.

2.2.1. Cold start-up status:

This procedure is followed when rotor temperature stage is less than 150 ^{o}C or the turbine is in stop/stand by condition for more than 18 hours. This procedure will take 5 hours to bring turbine from zero to rated speed about 3000 rpm.

a. Fresh steam pipe drying: Drying the pipe from the boiler to the main steam valve.

- Increase new steam pressure from 0 ~ 0.294 MPa at a rate of about 0.01 MPa/min (time is about 30 minutes).
- Keep the new steam pressure at 0.294 MPa (≈ 0.3 MPa) to dry the pipeline for about 20~30 minutes.
- Increase new steam pressure from 0.294 ~ 0.59 MPa at a rate of about 0.049 MPa/min (time is about 6 minutes).
- Increase the new steam pressure from 0.59 ~ 2 MPa at a rate of about 0.098 MPa/min (pressurization time is 14 minutes).

During the drying process, it is necessary to ensure that the temperature rise rate does not exceed 3 ~ 5 ^{o}C/min.

- Dry the pipe from the main steam valve to the Stop valve.
  - Check before drying.
    - Open the Stop turbine valve completely.
    - The four-pipe forward steam condensate relief valves are fully open.
    - Four turbine regulating valves fully closed.
  - Verify new steam parameters before the main steam valve to ensure: > 2.0MPa; 320 ^{o}C.
    + The anti-wear valve (the exhaust valve of the steam pipeline after the main steam valve and before the Stop valve) is fully open.
    + The discharge valve after the anti-wear valve on the quick discharge tank is completely closed.

- The exhaust valve after the anti-wear valve on the exhaust manifold is fully open. - The turbine protection and regulating oil system has been put into normal operation to open the Stop valve. - Check that the Stop turbine valve is fully closed.

b. The order of drying:

* Open the main steam valve by hand.

* Dry for about 5 ~ 10 minutes and at the same time check the amount of steam discharged through the drain valve.

After guaranteed drying, close the anti-wear condensate valves to the common exhaust pipe and the bypass valves of the main steam valve completely.

- Drying sequence.
  - Open the main steam valve by hand.
  - Dry for about 5 ~ 10 minutes and at the same time check the amount of steam discharged through the drain valve.
- Open the main steam valve by hand.
- Dry for about 5 ~ 10 minutes and at the same time check the amount of steam discharged through the drain valve.
- After guaranteed drying, close the anti-wear condensate valves to the common exhaust pipe and the bypass valves of the main steam valve completely.
- Drying the pipe from the Stop valve to the regulating valves

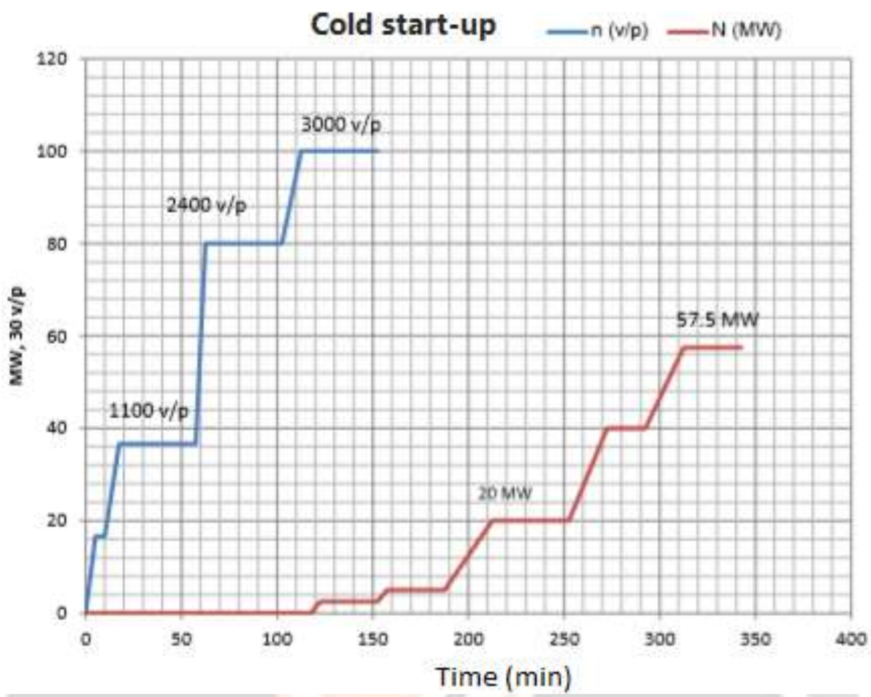

Fig -2: Cold start-up status characteristics

2.2.2. Warm start-up status:

Start the turbine in a warm state when the turbine body temperature in the adjustment stage reaches from (150 ~ 350) ^{o}C.

- *Dry the new steam pipe:*

When the new steam temperature is greater than the temperature of the turbine body by 50 ~ 100 ^{o}C and the superheat is ≥ 50 ^{o}C, open the stop valve after drying the pipeline before it and proceed to dry the transition steam pipes. After drying and the parameters meet the requirements of turbine. The drying process is similar to that of a cold start, only the parameters are different.

- *Parameters before starting.*

It is necessary to ensure that the new steam temperature must be higher than the turbine body temperature at the adjustment stage (150 ~ 350) ^{0}C and has a superheat temperature is more than 50 ^{o}C. Fresh steam pipeline system, transitional steam pipes after Stop valve and Stop valve must be drained of standing water. Depending on the turbine body temperature, if the turbine body temperature is > 250 ^{o}C, open the valve on the new steam supply line to insert the turbine shaft, while the turbine body temperature 150 ^{o}C < t < 250 ^{o}C is still taken from available steam.

The parameters of deflection, turbine body temperature difference, steam quality, pressure and lubricating oil temperature are similar to when starting from cold state. It is necessary to ensure that the new steam temperature must be higher than the turbine body temperature at the adjustment stage (150 ~ 350) ^{o}C and has a superheat of over 50 ^{o}C. New steam pipeline system, transitional steam pipes after Stop valve and Stop valve must be drained of standing water. Depending on the turbine body temperature, if the turbine body temperature is more than 250 ^{o}C, open the valve on the new steam supply line to insert the turbine shaft, while the turbine body temperature 150 ^{o}C < t < 250 ^{o}C is still taken from available steam.

The parameters of deflection, turbine body temperature difference, steam quality, pressure and lubricating oil temperature are similar to when starting from cold state.

- Sequence of turbine load increase rate in warm state and the parameters for the loading process are the table below:

Table 2. Parameters for the loading process:

Operating Procedure	Increase load from 2.5 MW to 20 MW	Keep load at 20MW for drying.	Increase load to 57.5 MW	Total
Load increase rate MW/min	~ 0,6	-	0,9375	
Time (minutes)	30	30	40	100

The warm start-up status characteristics are described in the figure 3.

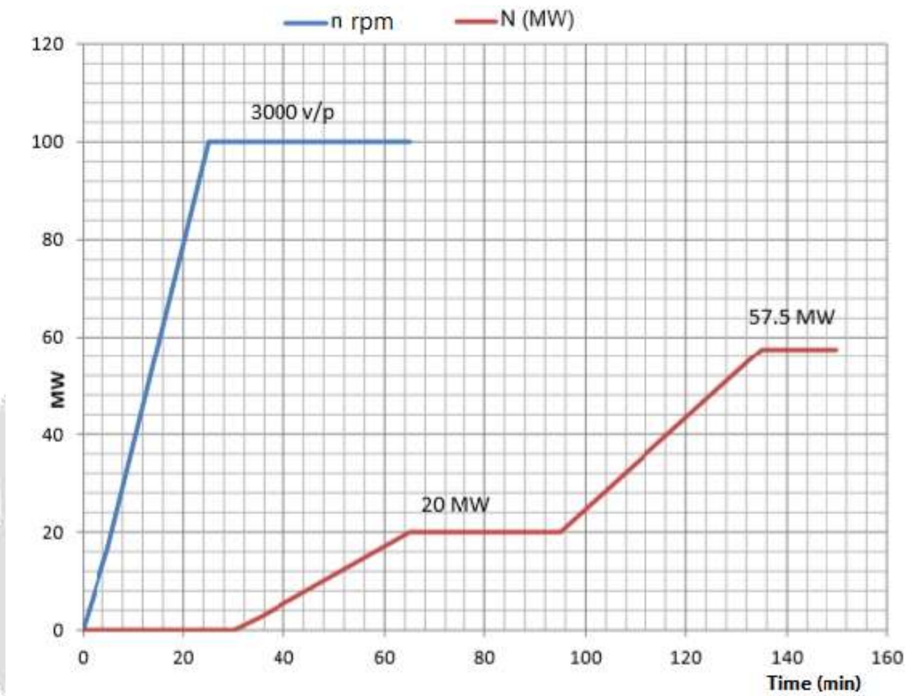

Fig -3: Warm start-up status characteristics

2.2.3. Hot start-up status:

Start the turbine in hot state when the turbine body temperature in the regulating stage reaches from ≥ 350 ^{o}C.
a. Dry the new steam pipe.
The process of drying new steam pipes in hot start mode is similar to cold start only with a difference in parameters.
b. The parameters need to be ensured before pulsing the turbine.
The new steam temperature must be greater than the turbine body temperature from (50 ~ 100) ^{o}C (ie 400 ~ 450 ^{o}C) and has a superheat of ≥ 50 ^{o}C . Note: Due to the turbine body temperature > 250 ^{o}C (available steam temperature), fresh steam must be taken to dry the turbine front axle.
Other parameters are the same as when starting from cold state, only the characteristics and parameters are different in table 3.

Table 3. Parameters for the speed increasing process:

Operating Procedure	Speed up to 4.7 to 500 rpm	Increase speed from 500 to 3000 rpm
Increase speed rate rpm	165	833
Time (min)	3	3

And the generator is connected to the power grid and increase the load. The same as in the case of cold start, only the parameters are different in table 4:

Table 4. Parameters for the loading process:

Operating Procedure	Increase load from 2.5 MW to 20 Mw	Keep load at 20MW for drying.	Increase load to 57.5 MW
Load increase rate MW/min	1.75	-	1.875
Time (minutes)	10	10	20

The figure 4 give the hot start-up status characteristics as below:

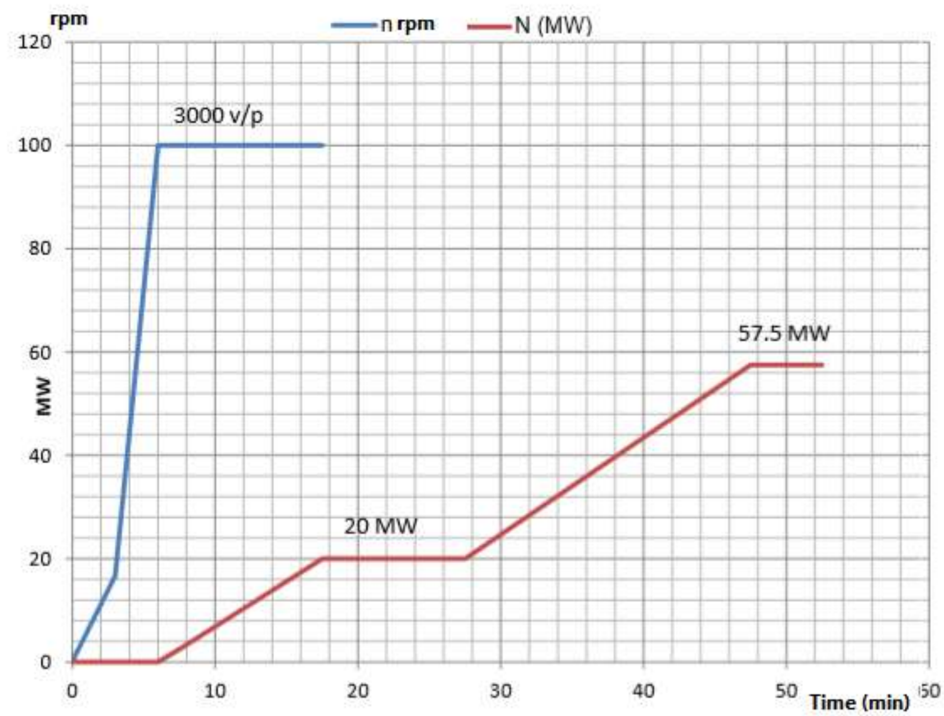

Fig -4: hot start-up status characteristics

For all three start-up status, there are some attentions in the process of increasing the unit load:

- In the process of increasing the load of the unit, it must to pay attention the working condition of the boiler to increase the load, the fresh steam temperature must increase according to the starting characteristics.
- To pay attention to adjust the leak pressure in the high-pressure chamber No. 3 to stabilize from 0.10 ~ 0.11 MPa, to avoid the leakage of steam entering the turbine front bearing affecting the lubrication in the front bearing.
- if there is an abnormal increase in vibration at the bearings, the load must be stopped immediately to dry or reduce the load and find the cause from which to take timely measures.
- After the processing is complete, it is allowed to continue to increase the load.
- After the deaerator has worked normally (pressure is 0.588MPa and temperature is 158 ^oC), open the valve on the steam line from the deaerator to completely insert the end of the turbine shaft and at the same time close on the steam line.

2.3. Some damages, common problems when starting turbine some damage, common problems when starting turbine

- *Deformation of the rotor during turbine stop.*

When the turbine (rotor) starts to get the stop status, it is still in a high temperature state. Meanwhile, we let the rotor cool down on its own in a stationary state, the rotor will be deformed (bent) due to the temperature difference between the upper body and the lower body of the turbine.

Stopping the turbine from the operating state creates a vertical temperature gradient with the upper body of the turbine being the part that has a higher temperature than the lower body. If the rotor is not rotated evenly at a certain speed threshold, it can cause the shaft to bend in the upper direction. The rotor rotated at low speed will make the heat distribution inside the turbine more uniform and minimize turbine distortion.

- *High temperature at the bearing.*

It is necessary to protect the shaft when the turbine is stopped that is also to protect the bearing from high temperature from the turbine shaft. If during turbine stop, we do not put the shaft and the lubricating oil system into operation, the high temperature transmitted from the rotor shaft can cause the oil in the bearing to evaporate quickly and fire. Putting the spindle into service currently that maintains an oil layer and protects the bearing from high temperatures, the babbit layer from overheating.

3. TO PROPOSE A OPTIMAL START-UP PROCEDURE

A steam turbine has a fixed end and moving end that are supported on independent pedestals. As the turbine is operated with the superheated steam (temperature above 535 oC). As the heating up start – up process of parts of turbine, thermal expansion will take place.

So, we need the temperature of one surface of turbine casing is exposed to atmospheric temperature of 35 oC while internal side is exposed to superheated steam. Due to this temperature differences, the expansion of turbine shaft will not be equal to that of turbine casing. The difference between these two expansions is called Differential Expansion of a turbine casing. This value is required to be as low as possible. But it will never be equal to zero due to practical limitations.

The detailed start processes as below:

- When the main steam temperature of the boiler reaches 250 ◦C, the steam pressure reaches 5 MPa starts to rotate. The steam pressure is not higher than 0.5 MPa, and the vacuum degree of condenser is higher than 0.05 MPa. When the rotor speed of turbine rises to 2000 rpm, the temperature rise rate of main steam temperature is 1.5 ◦C/ min.
- The main pressure reaches 370◦C, the preheating time of medium speed is calculated. During reasonable speed preheating, the time is 60 minutes. After that, the main temperature continues to increase.
- As the rotor speed of the steam turbine reaches 3000 rpm, the generator will be connected to the grid. Under the condition of different heating time, the main steam temperature rises to 535 ◦C for about 100 min.

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4. CONCLUSIONS

The section discussed a new point of view for the synthesis of the synthesis methods for start-up process. Most frequently used means of starting-up steam turbines may be mentioned atogether with their advantages and disadvantages are summarised.

- Using the constant pressure operation with throttle control that the instant live steam pressure in the entire load range, throttle control and ttypically two control valves but no control stage. This method has some advantages such as load step changes, low cost but it has high throttling losses in partial load operation.

- Constant pressure operation with nozzle group control; Constant live steam pressure in the entire load range Nozzle group control Typically four control valves Control stage; Load step changes High efficiency at partial load operation; The disadvantages of this method is also expensive control stage;
- Pure sliding pressure operation: Live steam pressure changes proportionally to live steam flow rate throttling in control valves typically two; This method has only the low cost but it required to quick load step changes for frequency control not possible

In addition to the above three methods, there are other methods such as: Modified sliding pressure operation; Modified sliding pressure/constant pressure operation.

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