OPTIMUM ECONOMY AND EFFICIENCY IN ENERGY CONSUMPTION DURING START-UP AND SHUT-DOWN OF 210 MW THERMAL POWER STATIONS

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Abstract—The paper reports the results of investigations for reduction in auxiliary power for reliable running of Indian thermal power generation plants with optimum economy and efficiency in power consumption. The problems during start-up, loading and shut-down, leading to delays, thus higher energy consumption, and measures to be adopted to overcome the same have been described.

Boiler feed pump Condensate extraction pump Energy conservation Forced draft fan High energy arc Induced draft fan Power station engineer Thermal power station

1. INTRODUCTION

Auxiliary power consumption is quite high in all Indian power stations, and as such, there is substantial scope for its minimization.

In order to study, analyse and recommend remedial measures, the following three sections are made for 200/210 MW units:

(1) Problems during start-up and shut-down leading to delay and measures adopted to overcome the same.
(2) Various measures to be adopted for reduction in auxiliary energy consumption during normal load.
(3) Factors responsible for low average load operation leading to high auxiliary power consumption as a percentage of generation and remedial measures thereof.

2. SITE TRIALS ANALYSIS OF PROBLEM OF DELAYS

The problems contributing to delay in starting/shut-down of the unit, thus leading to high energy inputs without power generation, have been analysed in the following four headings:

(1) boiler header blow-down and silica clearance
(2) turbine expansion problems
(3) problems in ignitors and oil guns
(4) longer generator dry out period after overhaul.

The time taken from the start of the first auxiliary to full loading of the unit almost always exceeds the given time in standard start-up curves recommended by suppliers like Bharat Heavy Electricals Ltd (BHEL). Since most of the auxiliaries are kept running from the beginning of the start-up period, the extended time calls for analysing the problems. In this regard, cold, warm and hot start-up curves need to be studied.

The time taken to start is invariably more than the given time in, say BHEL, start-up curves, as given in Fig. 1. It is possible to avoid the delay if start-up is performed according to the curves supplied by the suppliers.
2.1. Header blow-down and continuous blow-down (CBD) operation

(1) BHEL had earlier recommended blow-down at 10, 20, 30, 40 and 60 kg/cm$^2$. Delay was being caused as the boiler was required to be banked every time. Now, it is recognized that the number of blow-downs can be reduced without adverse effects on boiler water quality and silica clearance. Only one header blow-down at 20 kg/cm$^2$ is sufficient.

(2) Flushing of high pressure (HP) heaters during cold start-up should be continued.

(3) Continuous blow-down (CBD) flow at equilibrium conditions can be calculated as per the formula given below:

$$\text{CBD flow} = \frac{\text{Concentration of solids in feed water} \times \text{Total steam flow}}{\text{Concentration of solids in CBD} - \text{Concentration of solids in feed water}}$$

The concentration of solids/litre of water can be determined by evaporating the water and weighing the solid residuals.

(4) Unit drain tank should not be allowed to get contaminated, which may result from undesirable mixing of general service (GS) water lines with demineralized (DM) water circuits.

2.2. Ignitors and oil guns

After trip-out of the unit, the re-light of the boiler gets delayed due to a problem in establishing the ignitors and oil guns. It affects, in turn, turbine parameters, resulting in delay of unit start-up. Ignitors need consistent high field maintenance.

2.3. Problems and remedial measures

The problems and remedial measures for three types of ignitors, i.e. oil ignitors (which use differential pressure for flame scanning), ionic flame monitoring (IFM) and high energy arc (HEA), are analysed below:

(1) Chocking off/leaking off differential pressure (d.p.) lines.

(2) Deformation of ignitor horns causing variation in d.p. settings.

(3) Clinker formation at the tip.

(4) James Burry valves gear train jamming and motor brush damages.

(5) Soot deposits in spark gaps requiring frequent cleaning of spark plugs.
2.4. Remedial practices

(1) Daily cleaning of ignitor spark plugs.
(2) Daily checking of cleaning of James Burry valves, i.e. cleaning of gear trains, checking of motor brushes, etc.
(3) Daily blowing of d.p. sensing lines by air and sometimes cleaning by rods.
(4) Oil guns be purged continuously for 8 h by steam whenever it is withdrawn or on boiler tripping, thereby no delays in next light-up or for taking guns in service.
(5) Regular maintenance will increase their availability.
(6) James Burry valves be modified with ball bearings, and there will be no jamming problems.
(7) For frequent failure of IFM cards, replacement of transformers is the only solution.

3. DELAY DUE TO TURBINE EXPANSION AND ASSOCIATED PROBLEMS

The expansion problem of the turbine during rolling causes delay in start-up and loading of the unit which in turn, causes unnecessary auxiliary energy consumption. The problems are listed and analysed below:

(1) Flange and stud heating is given during cold rolling at about 1200 RPM to arrest turbine expansion. For early effect, both HPT and IPT stud and flange heating is given simultaneously.
Delay in boiler light-up after trip-out of the unit causes severe negative expansion problems.
Rotor heating is given every time during hot rolling.
(2) Common rotor heating systems for all 210 MW units need to be introduced so that, during hot rolling, rotor heating steam of desired parameters can be made available. Proper isolation between units needs, however, to be ensured.
(3) Operating instructions of suppliers like BHEL, ABB, NEI, Siemens and GEC, needs to be followed for flange, stud and rotor heating.

4. DELAY DUE TO GENERATOR WINDINGS DRY-OUT

Generator windings need to be dried after long shut-down/overhaul in the shortest possible time. It is done by rolling the turbine, running it for hours, causing enormous fuel and auxiliary power consumption. In spite of satisfactory values of insulation resistance (IR) and absorption coefficient, the polarization index (PI) remains low, necessitating drying out of the generator by rolling with dry compressed air at 0.2 kg/cm². It generally takes 24 h or more to get suitable PI values of more than two, leading to undesirable fuel oil consumption. It clearly requires study to minimize the dry-out time as developed in a power plant mechanism illustrated in Fig. 1, eliminating the need for rolling the unit for dry-out.

5. STARTING/LDING AND STOPPING OF POWER GENERATING UNIT WITH MINIMUM NUMBER OF AUXILIARIES

Higher consumption of works power during starting of the unit is compounded by starting both ID-FD fans, CW pumps, etc. and being kept running throughout the extended start-up period. During the start-up period, one set of auxiliaries is required to save energy. Two pumps or fans running in parallel, when only one is required, amounts to wastage equivalent to the "no load losses" of the second auxiliary. The utility of the second pump running is just about 30% benefits as compared to the first pump only in operation. No load losses, in the case of pumps, are more than 50% of the full load power. This requires studies for standardization of starting and stopping of various auxiliaries which is discussed below:

5.1. Timely running pays
Starting of the auxiliaries much earlier than required times MUST NOT BE DONE.
5.2. **Air cycles**

Only one cycle, i.e. one induced and forced draught (ID and FD) fan, should be run during cold and warm periods.

5.3. **PA fans**

Both primary air (PA) fans are started before putting in the first coal mill, while only one fan is sufficient for two mills operation.

5.4. **Boiler feed pump (BFP), condensate extraction pumps (CEP) and starting oil pumps (SOP)**

The BFP is not required to be run during initial light-up of the boiler. Boiler filling can be done by emergency lift for filling pump. The first BFP can be started at about 20 kg/cm² boiler pressure, while the second is required after 80–100 MW load for 210 MW unit. Both CEPs may not be necessary during steam conditioning of the turbine. It is better to avoid the practice of starting the SOP during withdrawal of turbine and continuing its operation for hours together. At the time of turbine trip, the SOP is not required to be started. The a.c. lube oil pump needs to be started as soon as the speed reaches 2800 RPM and continued until the turbine cools down properly by barring gear.

5.5. **Circulating water pumps (CWP)**

Both CW pumps are not required during start-up, except in isolated cases. CW pumps, in general, should be taken into service just before steam conditioning. Only one pump may be sufficient during rolling, synchronization and part load operations. The second pump is needed when improvements in vacuum will offset the heat equivalent of power consumption by the second pump. The running cost must be offset by extra output from the main unit.

5.6. **Cooling tower (CT) fans operation**

Operate cooling tower (CT) fans, say five initially, and later additional fans may be run depending upon the CW temperature and condenser vacuum. CT fans should be stopped one after another on withdrawal of the unit.

5.7. **Forced cooling of boiler and turbine**

Sufficient time can be saved within the constraints of the cooling curves (Fig. 2) by forced cooling of the boiler during outage. It would benefit in reduced shut-down time and, hence, early availability of the unit. For turbines, natural cooling is preferred.

The key analysis of reductions in auxiliary time for ENCON (energy conservation) leads us to standardization of practices, which is presented below.

6. **STANDARDIZATION APPROACHES FOR MINIMUM NUMBER AND TIMELY RUNNING OF AUXILIARIES WHILE START-UP/SHUT-DOWN OF UNIT**

Keeping in view safety, reliability and efficiency, the following standard practices are suggested.

1. Run only one air cycle for boiler light-up and till synchronization, while the second ID fan is run before taking the first coal mill and the second FD fan starts at about 50 MW.

2. One PA fan may be taken on load in the beginning for taking the first coal mill, the second taken by PA header pressure as the subsequent coal mills are cut-in. However, they may perform suitable to individual TPS needs. Air heater seals and damper leakage shall be attended during every shut-down of sufficient duration.

3. Boiler filling initially should be done by fill pump. The first BFP can be started at 20 kg/cm² and the second at about 100 MW.

4. Operate only one CW pump during starting while the second pump is run at a point when the heat rate increases due to loss of vacuum exceeding the additional CW pump's electricity use. At times, both CW pumps are required to be run for vacuum pull-up. However, the economical unit load for start of the second CW pump may be ascertained for a particular power station. It can be around 90 MW, but must withdraw one pump after the unit is shut-down. Also both CW pumps should be stopped if the unit is stopped for maintenance beyond 36 h.
5. BENEFITS OF STANDARD PRACTICE

Depending upon the site equipment conditions above stated standard operation practices should be followed for generating more power, and its applied benefits are detailed below:

(5) The starting oil pump should not be started during withdrawal of the turbine. Only the a.c. lube oil pump needs to be started at 2800 rpm.

(6) On an average, for all plants, all CT fans initially need not be taken into service.

(7) Both CEPs should be taken into service before vacuum pulling.

(8) Forced boiler cooling be done within the constraints of cooling curves given by suppliers (say BHEL, ABB, etc.).
(1) By adopting single cycle operation, a saving of 15% energy consumption by the second sets of FD, ID, PA fans and CW pumps is ensured during light-up and loading periods.
(2) The time taken for unit start-up is reduced, leading to savings in auxiliary energy consumption.

8. CONCLUSIONS

(1) With the site investigations conducted and discussions held, it has been found that, during light-up and withdrawal of the unit, only one set of auxiliaries should be run to economize on power consumption.
(2) Since the time taken to start the unit is invariably more than the given time in the start-up curves supplied by manufacturers, the delay can be curtailed to the maximum extent possible by performing timely operations.
(3) Poor maintenance or delayed mal-operations cause longer start-up and loading of the unit. This delay leads to unproductive auxiliary energy consumption. Analysis of the problems, followed by proper remedial measures, would help in immense savings of energy.
(4) Specific action oriented strategies can deliver excellent results, except whenever implemented in isolation, as plant operations are inter-linked and inter-dependent.

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