



**REPORT OF THE COMMITTEE
TO RECOMMEND NEXT HIGHER SIZE
OF
COAL FIRED THERMAL POWER
STATIONS**



**Central Electricity Authority
Ministry of Power
Government of India
New Delhi
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FOREWORD

Giant strides have been made in the Indian electricity sector in the past five decades. The generating capacity which was a meager 1362 MW at the time of independence has presently increased to 1,09,868 MW, thus growing over 80 times. The demand for electricity has, however, overtaken the supply and the gap has been increasing. The rapid economic growth for which the country is poised in the wake of economic reforms and globalization would lead to further increased demand growth. In keeping with the goal of the Government of India to supply power on demand by the year 2012, a capacity addition programme of over 1,00,000 MW has been envisaged for the next decade spanning over 10th and 11th plan periods.

Share of thermal generation in the total generation in the country has consistently increased to a peak of over 84% in the last year. In the capacity addition programme envisaged for the next decade, about 64,000 MW is envisaged from thermal stations thus accounting for about 59% of the total capacity addition envisaged. This necessitates a quantum jump in the pace of installation of thermal capacity from about 3000 MW/year to over 6000 MW/yr over the next decade.

With the ever rising share of thermal generation and the growing environmental concerns, the efficiency considerations of thermal stations have assumed greater significance. Constant efforts have been made in the past to improve the technology and efficiency of thermal generation, and units with higher steam parameters and efficiency have been progressively introduced. The contribution of bigger unit sizes has also been increasing and today 200/210 and 500 MW units constitute about 60% of total thermal capacity. The 500 MW units have operated for the last 20 years and have been consistently showing better performance than the lower unit sizes.

It was considered that inducting more efficient and higher size coal fired units rapidly is the most viable strategy to achieve the capacity addition required and the **"Committee to Recommend Next Higher Unit Size of Coal Fired Thermal Power Stations"** was set up by CEA under the chairmanship of Member (Thermal) CEA to recommend the most suitable unit size and steam parameters for adoption in the country. The Committee has representatives from BHEL, NTPC, Planning Commission and other major utilities in state and private sector. The Committee had prolonged and meaningful discussions on various issues involved. I am happy that the report of the Committee has been finalized.

Considering the very successful operation of 500 MW units over the last decade, and with supercritical technology & large unit sizes achieving high reliability and availability internationally, it is recommended to adopt units of 800-1000 MW with supercritical parameters in the country. I am sure that adoption of large size units would provide much needed fillip to the pace of thermal capacity addition and also result in reduced impact on environment due to efficiency enhancement.

However, to really harness the benefits of higher size units, matching efforts would be required by coal sector to provide consistent quality coal; free of extraneous matter. It would also have to be ensured that appropriate technologies are selected by the manufacturers for performance with high reliability under Indian conditions.

Long and indepth deliberations on various intricate aspects of thermal power plant design, operation, and economics etc. spanning over 2 years have been involved in preparation of the report. I take this opportunity to congratulate Sh. R.K. Jain, Member (Thermal) CEA and his team for having

successfully completed this task. My thanks are also due to all member organizations who have made valuable contributions to the deliberations of the Committee.

A handwritten signature in black ink, appearing to read 'H.L. Bajaj', written in a cursive style and underlined.

(H.L. Bajaj)

Chairman (CEA)

7th November, 2003

CONTENTS

1. BACKGROUND	2
2. POWER SECTOR DEVELOPMENT	5
3. PERSPECTIVE FOR POWER DEVELOPMENT (2002-2020)	6
3.1 POWER DEVELOPMENT SCENARIO UPTO END 11 TH PLAN (2002-12)	6
3.2 POWER DEVELOPMENT SCENARIO BEYOND 11 TH PLAN (2012-20).	6
4. DELIBERATIONS OF THE COMMITTEE	8
4.1 OPERATING EXPERIENCE	9
4.2 SYSTEM CAPABILITY & GRID RELATED ISSUES	12
4.3 LARGE UNIT SIZES AVAILABLE WORLD WIDE FOR ADOPTION	14
4.4 PROVEN/ESTABLISHED TECHNOLOGY	16
4.5 STEAM PARAMETERS & CYCLE CONFIGURATION	17
4.6 COST ECONOMICS	18
4.7 INDIGENOUS CAPACITY BUILDING	19
4.8 ENVIRONMENTAL BENEFITS OF HIGHER SIZE UNITS	20
4.9 OTHER ISSUES	20
4.10 STRATEGY FOR INDUCTION	21
5. CONCLUSIONS	23

REPORT OF THE COMMITTEE TO RECOMMEND NEXT HIGHER UNIT SIZE FOR COAL FIRED THERMAL POWER STATIONS

1. Background

A sub-group under the Advisory Group on technology development was set up by the Government of India (then Ministry of Irrigation and Power) in the year 1985 to recommend the next higher size of Thermal Turbo Generator and the desirability of going in for super critical versus sub critical steam parameters of the boiler. The sub-group submitted its report in April, 1986 wherein, besides other recommendations it opined **that 500 MW units would be adequate to meet the requirement of power development till the year 2000 and a further review of the situation would be required in the year 1990-91.** In pursuance of this recommendation of the Sub-group, the Ministry of Energy reconstituted the Sub-group in 1989 to determine the next higher size of thermal turbo-generator and next higher steam conditions in power cycle. The Sub-group submitted its report in April, 1990 recommending that **next higher size units of 750 MW rating with once through design may be adopted and the choice of sub critical/super critical parameters may be left open to the utilities to decide.**

As a result of rapid capacity addition in the last decade, the total installed capacity has reached 1,09,868 MW with thermal capacity of 77868 MW as on 1st November 2003. Electricity generation has come to be increasingly dependent on thermal generation as hydro and nuclear generation have not kept pace with the plans due to various reasons. Thermal power sector presently accounts for about **70 %** of the total installed capacity in the country and in the year 2002-2003 over **84 %** of the country's total electricity generation have been obtained from thermal stations. This reliance on thermal generation is expected to continue.

Due to rapidly expanding demand for power, a capacity addition of over 1 lakh MW is planned for the next decade upto the year 2011-12. More than two third of this capacity addition is expected to be from thermal stations. A large number

of gas turbines have been added in the Indian power sector, significantly contributing to installed capacity and generation. However, thermal generation is largely coal based accounting for about 85 % of the installed thermal capacity. The average thermal capacity addition in the past years has remained stagnant at about 2500-3000 MW per year after introduction of 210/500 MW units. Amongst several factors affecting pace of capacity addition, unit size is considered to be very important and with this view it was thought to consider adopting higher unit sizes for advancing the pace of capacity addition as required. Also, with sufficient operating experience gained through operation of 500 MW units and also availability of feed back of once through sub critical units in the country, a basis for further raising unit size and parameters further got prepared. The first beginning in this regard was made by NTPC's proposal for 3 Nos. 660 MW units for Sipat thermal power project based on super critical parameters.

However, to decide on optimal size of the thermal units based on various techno-economic considerations, the present Committee has been constituted by the Central Electricity Authority vide **Office Memorandum No. 5-41/2001/Secy(CEA)/2220 dated 28.9.2001** (Appendix -1) with composition as follows:

1 Member (Thermal),CEA	Chairman
2. Jt.Secretary (Thermal), MOP	Member
3. Advisor (Energy), Planning 1` commission	Member
4. Director (Technical),NTPC	Member
5. Director (Power), BHEL	Member
6. Member (Generation) TNEB	Member
7. Technical Member (Generation)MSEB	Member
8. Member (Generation) MPEB	Member
9. Director (Thermal) APGENCO	Member
10. Director (Technical), BSES	Member
11. Executive Director, Tata Power	Member
12. Member Secretary NREB	Member
13. Member Secretary WREB	Member
14. Member Secretary SREB	Member

15.Member Secretary EREB	Member
16. Chief Engineer (IRP) CEA	Member
17.Chief Engineer (GM) CEA	Member
18. Chief Engineer (SPA) CEA	Member
19.Chief Engineer (TA) CEA	Member
20.Chief Engineer (TE&TD) CEA	Member Secretary

The terms of reference of the committee are as follows:-

- 1) To recommend the next higher size of coal fired thermal units keeping in view the relevant technical aspects, capacity addition programme, global scenario regarding higher size units, Indian grid complexities, economic aspects, indigenous manufacturing capabilities, human resource aspects etc.
- 2) To recommend the next higher steam conditions (parameters) in power cycle.

2. Power Sector Development

The Indian Power Sector comprised of unit of sizes 100 MW and below upto 70s when the first 200 MW unit was introduced in 1977. Thereafter, this became almost the standard size and most units added during the next two decades were of 200/210 MW. The first 500 MW unit was commissioned in 1984 and a total of 27 nos. 500 MW units have been commissioned since then. These 200/210 and 500 MW units form the backbone of Indian Power Sector and together account for over 60% of the present thermal power capacity in the country. Meanwhile, 250 MW units have also evolved by upgrading the designs of 210 MW units. The 500 MW units have consistently recorded remarkable performance with their plant load factors far exceeding the other capacity groups. Improved and reliable designs indigenously evolved over a period through feed backs from operating utilities and constant efforts of manufacturers in solving the past problems deserve significant credit. With the operation of these units, the Indian utilities have also become conversant with use of indigenous coal, stringent water chemistry and other operational and safety considerations associated with higher sized units and steam parameters.

The indigenous manufacturing capabilities have also been upgraded considerably and most 500 MW units have been indigenously supplied. BHEL have also entered into collaborations for manufacture of higher size turbo-generators and boilers using supercritical parameters.

3. Perspective For Power Development (2002-2020)

3.1 Power Development Scenario upto end 11th Plan (2002-12)

As per the “5th National Power Plan (2002-2012)” prepared by CEA a need based installed capacity of the order of 2,12,000 MW is required by the end of 11th plan based on demand projections of 16th Electric Power Survey and a system reliability level of Loss of Load Probability (LOLP) less than 1% for the country. The primary resources for electric power generation are water, fossil fuel (coal, lignite, oil and natural gas) and nuclear energy. These would continue to serve as major sources of power generation in the long run, though various forms of renewable sources viz, wind, bio-mass, tides etc will also contribute to meeting the demand.

Based on the report of the Working Group on Power constituted by Planning Commission, a capacity addition of 41,110 MW is targeted in 10th plan comprising 14,393 MW hydro, 25,417 MW thermal and 1,300 MW Nuclear. Out of the total thermal capacity of 25,417 MW, the coal/lignite based capacity shall be 20,053 MW. For 11th Plan, CEA has identified a capacity addition requirement of 67,439 MW comprising of 23,358 MW hydro, 38,166 MW thermal and 5,915 MW nuclear, Out of the total thermal capacity of 38,166 MW, the coal/lignite based capacity shall be 30,411 MW. The 11th Plan programme is comparatively large so as to provide not only for normal growth during the 11th Plan period but also to compensate for any shortfall in the capacity addition during the 10th Plan period.

3.2 Power Development Scenario Beyond 11th Plan (2012-20).

The Indian Power System requirement had been assessed to need a hydro power and thermal/nuclear power mix in the ratio of 40:60 for flexibility in system operation depending on typical load pattern. To achieve this mix and to accelerate the hydro power development, 50,000 MW Hydro electric initiative was launched by Hon'ble Prime Minister of India on May 24, 2003.

Hydro wing, CEA has identified a hydro capacity of 35,523 MW for yielding benefits during the 12th Plan period (2012-2017). These schemes have been identified based on their present status as available with the CEA. Nuclear Power Corporation has planned to add nuclear power projects aggregating to 10,000 MW for giving benefits between 2012-2020. With the capacity addition of 41,110 MW targeted for the 10th plan and 67,439 MW assessed as required during the 11th plan , it is expected that 'power to all' would be achieved by 2012. A preliminary study has been carried out by CEA to estimate the capacity addition required between 2012-2020 extending the demand projections of 16th EPS. The optimal plan of the study has indicated a capacity addition requirement of 1,35,000 MW during this period comprising of 35,500 MW hydro, 10,000 MW nuclear and 89,500 MW thermal (including 6,500 MW gas based plants). The coal based capacity required shall be about 83,000 MW during the period 2012-2020. Any shortfall in achieving hydro capacity addition would also have to be made good by additional coal based projects.

Keeping in view the huge power generation capacity requirement to be added during the 11th and 12th Plan periods, an urgent need is felt for large scale thermal power development in an environment friendly manner.

4. Deliberations Of The Committee

The Committee held five meetings on 23rd November 2001, 28th December 2001, 23rd April 2003, 24th July 2003 and 15th October 2003. After the second meeting, the committee appointed a subcommittee under chairmanship of Sh. V.S Verma then CE(TE&TD) CEA and representatives from NTPC, BHEL and MSEB for examining in detail the technological issues associated with unit size and recommend suitable unit size and steam parameters. The sub-committee held 3 meetings on 18th January 2002, 7th February 2002 & 11th October 2002. The record notes of discussions of the main committee and sub committee are placed at Appendix-2A to 2H.

The committee deliberated on the following aspects to zero in on the criteria for selection of next higher unit size.

- Operating Experience
- System capability & Grid related issues
- Larger Unit sizes available world wide for adoption.
- Proven/established technology
- Steam parameters & cycle configuration
- Cost Economics
- Indigenous capacity building
- Strategy for induction

Inputs were also received by the committee from expert groups from NTPC/CEA who visited Japan, USA and various European countries for study of supercritical units. Presentation were made to the committee by Babcock and Wilcox USA on 22.01.2002 and BHEL on 28.12.2001 & 24.7.2003. Copies of these presentations are annexed at Appendix 3 A to C.

The salient observation of the committee on various issues are as follows:-

4.1 Operating experience

(i) Unit Size

The major growth in thermal generation capacity took place during 7th to 9th five year plans after the introduction of 200/210 MW units in 1977. The increase in unit size had a direct bearing on rate of thermal capacity additions leading to large capacity additions.

The largest size unit was 30 MW in 1950. It progressively increased to 60 MW in 60s, the most prevalent sizes adopted being 30, 60 & 62.5 MW. Most of these units were non-reheat units, and had comparatively lower efficiencies. The first reheat unit of 82.5 MW was commissioned at Bandel TPS of WBSEB in 1966. With the adoption of reheat system, unit size could be increased and larger size units of 110/120/140 MW were the normal size of the units added in 70s. A few non re-heat units of 100 MW were also added. The first 200 MW unit of Russian (LMZ) design was commissioned at Obra TPS of UPSEB in 1977. Thereafter this became almost the standard unit size and most of the units added during next two decades were of 200/210 MW. This also remained the highest unit size in the Indian thermal power sector upto 1984 till the first 500 MW unit was commissioned at Trombay TPS of Tata Electric Company. Today 27 Nos. 500 MW units aggregating to 13,500 MW are operational. In 1983, the KWU design 210 MW units came into being and first such unit was commissioned at Korba west TPS of MPEB in June 1983. Higher steam parameters were adopted in these units resulting into better cycle heat rates.

200/210/250 MW and 500 MW units form the backbone of Indian power industry and together constitute about 60% of total thermal capacity. Most of the 200/210 & 500 MW units have been built indigenously.

Majority of the thermal projects are in the Central and State sector, leaving only around 11% of installed thermal capacity in private sector.

(ii) Plant Load Factor (PLF)

As can be seen, a large number of thermal units with various capacities /sizes are operational in the country. The plant load factor of thermal power stations has been consistently improving from around 54% prevailing in 1990-91 to over 72% in 2002-03. There has been large variation in performance of thermal units across various regions and operating utilities. The performance of central sector and private has been consistently higher than the state sector. However, certain well-run state utilities have achieved and even surpassed the performance of central and private sector.

With most of the operational constraints faced on account of poor quality Indian coal being overcome by sustained indigenous R&D feed back from operating utilities, the 200/210 MW and 500 MW units have achieved a consistently high performance. The PLF of 500 MW units has been consistently higher than the average all India plant load factors and PLF for 200/210 MW units as can be seen from Table 1. This may be partly due to the fact that most of the 500 MW units are being operated by Central Sector and well run SEBs.

TABLE – 1 Plant Load Factors Of 210/500 MW units

(All fig. are in %age)

S. No.	Year	PLF All India average	PLF 200/210 MW	PLF 500 MW
1.	1990-91	53.9	60.24	60.89
2.	1991-92	55.3	61.02	68.42
3.	1992-93	57.1	--	--
4.	1993-94	61.0	--	--
5.	1994-95	60.0	66.01	68.14
6.	1995-96	63.0	68.14	79.99
7.	1996-97	64.4	70.32	78.14
8.	1997-98	64.7	71.13	73.69
9.	1998-99	64.6	71.43	71.91
10.	1999-00	67.3	74.00	77.62

11.	2000-01	69.0	75.28	79.77
12.	2001-02	69.9	75.8	80.7
13.	2002-03	72.2	78.3	82.0

The 500 MW units also involve a technological shift from the natural circulation boilers to assisted circulation boilers and increase in main steam pressure to 170 kg/cm². These also involve turbo driven BFPs as against motor driven BFPs in units of 200/210 MW. The once through technology has also been introduced in Talcher 500 MW sub-critical units and the performance has been satisfactory. Thus the operational experience so gained would be useful in installation and operation of super critical units of higher size and the teething problems are expected to be much less on account of the experience and preparedness from operation of 500 MW units.

With the progressive increase in installed capacity, higher share of thermal generation and large peak to off peak ratios, backing down (part load operation), and cyclic operation of thermal units would become imminent. Super critical thermal units offer better operational profile in such an environment.

(iii) Heat Rate

With the increase in unit size and higher parameters, there has been a remarkable increase in the design efficiencies of the thermal units. Heat rates of different sizes of thermal units are indicated in Table 2. However, based on the data received from power plants and also energy audits carried out by CEA at various stations, it is seen that large number of power plants are operating with heat rates significantly above their design values.

TABLE – 2 Heat Rate of Different Unit Sizes

S. No.	Unit Size	Parameter Pressure(kg/cm²) MS temp ⁰C/ RH temp ⁰C	Turbine Cycle Heat Rate at 0% make up and 33⁰C C. W. Temperature (Kcal/hr)
1.	200/210 MW LMZ	130/535/535	2060
2.	210 MW KWU	150/535/535	1980
3.	500 MW	170/537/537	1940 (Turbo BFP)

However, in general the efficiency of 210 to 500 MW units has been generally better than the smaller size units with respect to their design values. The reasons for higher heat rates are mainly lack of adequate stress on efficient operation, part load operation of the units, outage of unit HP heaters etc. The operating utilities would therefore be required to upgrade their operation practices and skills to really achieve the benefits of higher efficiency associated with higher size of super critical units.

4.2 System capability & Grid related issues

(i) System Capability

At present Northern, Western and Southern regional systems have 500 MW thermal unit size as the largest unit in operation. In Southern Region a 1000 MW

nuclear unit is presently under installation. With the installation of number of such large units, adequate experience have been gained about their performance in the system. From consideration of economy it is desirable that large size units are operated at base load.

(ii) Stability Considerations

From consideration of stability, the system should be able to withstand contingencies involving outage of one such unit without loss of grid stability. The stability studies show that the system planned for 10th and 11th Plan periods, can generally withstand outage of units up to 1000 MW and 1300 MW respectively. However, the location for placing such size of units would need to be checked for which specific studies would be required before finalizing any particular project proposal.

Further, if the precedent conditions are '*normal*', the loss of one unit should not cause dip of frequency below the setting for U/F load shedding. The '*normal*' operating precedent condition in the Indian system may be taken as one in which the operation frequency is above 49.5 Hz and no spinning reserve. The first set of U/F load shedding is set at 48.4 Hz. As such, the largest size of unit should be limited so that frequency dip on account of outage of one such unit is less than one Hz.

(iii) Future Grid Inter Connections

At present, ER, NER and WR are already in synchronous operation and NR would also be integrated with Tala Transmission system, which is expected to be commissioned by the end of 10th Plan. As such, the "K" factor (Power Number) of this network by the end of 10th Plan would be quite large- in the range of 2000 to 3000 MW/Hz. In such system dip in frequency following outage of 1000 MW unit would be less than 0.5 Hz.

The Southern Region would remain asynchronously interconnected with rest of the all-India Grid till the end of 11th Plan. The present power number of Southern

Region is of the order of 700 MW and with growth in demand and generation capacity, the power number of SR System would be in the range of 1000-1200 MW/Hz by the end of 10th Plan. For this power number, the dip in frequency, following outage of a 1000 MW unit would be in the range of 0.8 Hz to 1.0 Hz. As such unit size of up to 1000 is adoptable in SR from 10th Plan end onwards.

After integration of all India grid, the power number from beginning of 12th Plan and onwards would be more than 3000 MW per Hz and unit size of 1000 MW would be acceptable anywhere in the system.

4.3 Large Unit Sizes Available World Wide For Adoption

Super-critical units have been operational in the world for the last three decades in various unit sizes ranging from 500 to 1300 MW. A large number of units sizes with various technology and configurations are available.

The larger unit sizes available worldwide were reviewed by the committee as per list enclosed at Appendix 4. It is seen that a number of countries namely Japan, South Korea, Germany, Netherlands and Italy have gone for a large number of supercritical higher size units in 90s. Large number of supercritical units upto 1000 MW were also installed in USA & Japan from 1960s to 80s. However, in USA, installations have reduced considerably over last decade due to a shift from coal based to gas based generation from environmental consideration. Most of the 1000 MW units installed over the last decade are in Japan. Considering the past Indian operational feed back and our preference for conservative designs offering high reliability and availability, the objective has been to select unit size and technology which could offer optimum reliability and efficiency for Indian conditions.

Keeping this in view it is felt that the unit size shall be so chosen that it corresponds to proven large unit sizes and taking into consideration our usual design practices with respect to boiler sizing as well as the indigenous coal characteristics. The largest furnace sizes supplied by BHEL's collaborators M/s Babcock Borsig Power is for 917 MW coal fired unit at Heyden TPS (furnace

size 23.8m x17.1m)and 930 MW with lignite at Lippindorf TPS (furnace size 22.9mx22.9m) and these would correspond to about 750 MW and 1000 MW respectively with Indian coals. BHEL also made a comparative study to examine the techno-economics of 660 Vs 800 MW unit size and have found that for same steam parameters, 800 MW unit size is expected to offer a marginal better heat rate of about 7-8 Kcal/Kwh as compared to 660 MW unit size on account of more optimized flows in 800 MW units. Further the initial cost of 800 MW units is expected to be about 4 - 5% lower than the 660 MW units on per MW basis. The cost of generation from 800 MW units is thus expected to be about 3.4% lower than that for 660 MW unit.

Based on the above analysis & general consensus in the committee, it was opined that a unit size of 800 to 1000 MW may be taken as the next higher unit size and the most optimum size based on site specific techno-economic optimization may be adopted for specific sites. NTPC however felt that 660 MW units should be adopted initially for few projects and then higher unit size may be adopted with ultra supercritical parameters in the next phase. However, the objective of the committee is to choose unit size with long term perspective, consideration of economics and faster capacity addition. The previous scale ups from 100 to 210 MW and from 210 MW to 500 MW have been significantly higher of the order of 200% to 225%. Also, BHEL are fully confident and geared up for manufacturing units upto 1000 MW sizes and higher size units of 800 MW offer better economics. Besides, ultra supercritical technology is still in the development state and would take long before it matures for adoption under Indian conditions and the risk profile and techno-economics of this technology would be totally different. Thus, it is recommended that unit size of 800-1000 MW may be adopted as next higher unit size. However sharing the NTPC concerns, the committee recommends that only proven & established technologies are adopted. Special attention must be paid to ensure that technology chosen is able to perform with high reliability with Indian coal and under Indian operating conditions. Adequate measures for proper technology selection and absorption and stringent quality control should be taken for higher size units.

4.4 Proven/established technology

(i) Boiler

An important design consideration for boiler is the type of tubing adopted for furnace. Both spiral tubing and vertical tubing are available. The American & European manufacturers have adopted spiral tubing while the Japanese manufacturers has adopted vertical tubing. The spiral tubing offers an advantage of lesser number of tubes and therefore more tube for the same size/flow and also uniform heat absorption across the heating surfaces. However, it involves a complex support structure and is relatively difficult to maintain. The vertical tubing is comparatively a recent development. and is adopted on large scale in Japan and is reported to be operating satisfactory. Other manufacturers have also attempted vertical tube designs. Considering the past Indian experience of vertical tube design in 500 MW units it would be preferable to adopt vertical tube designs for higher size units also for ease of maintainance. However, keeping in view the limited availability of vertical tube design to a few manufacturers, the options for both spiral and vertical tube designs may be kept open.

Various manufacturers have different start ups /circulations systems with drains to economiser, deareator etc. While some systems offer better efficiencies, the issue is not of much significance because these systems are used only in start ups and very low load operations of less than 40% loads. Besides, each manufacturer has his own proven system. Thus the standard circulating/start up system of the manufacturer may be adopted.

(ii) Turbine

Both combined HP-IP casing and separate HP-IP casing design are available and are operating satisfactorily. Combined HP-IP casing designs have also been adopted for some of the 500 MW units in the country and have performed satisfactorily. In view of the above both the types of machines may be acceptable.

An important design consideration however, is the highest feed water heater extraction and final feed water temperature. Some turbine manufacturers provide extraction from HP turbine thus achieving final feed water temperature of about 290°C. The conventional designs with highest feed water extraction from CRH line on the other hand is able to achieve a final feed water temperature of about 270 °C. The higher feed water temp. in case of HP extraction leads to a marginally better efficiency of 0.7 %. However, such a system involves additional heaters, higher total flows, and an increase in TG bay width which consequently increases civil works etc. Thus it is recommended to leave both the options open as the relative advantages of the two options would vary from site to site based on fuel costs etc.

The turbine designs should be fully optimized with respect to our ambient temperature conditions so as to achieve best possible efficiency for the higher size units.

4.5 Steam parameters & cycle configuration

World over while a large variation in units sizes have been observed, the steam parameters have been mostly restricted to 246 to 266 kg/cm² for main steam pressure and main steam/reheat temperature of 538/538, 538/566, 566/593 °C . The ultra supercritical parameters with pressures of about 325 kg/cm² at 620/620 °C are also being tried. The relative efficiency improvement from various parameters are indicated in Table 3.

TABLE –3 Efficiency Improvement For Higher Parameters

S. No.	Steam Parameter		Efficiency (%)	Increase in Efficiency (%)	Cumulative Increase in Efficiency (%)
	Pressure (kg/cm ²)	Temperature (MS/RH)			
1.	169	538 ⁰ /538 ⁰ C	38.6	Base	
2.	246	538 ⁰ /538 ⁰ C	39.29	0.69	0.69
3.	246	538 ⁰ /566 ⁰ C	39.56	0.27	0.96
4.	246	566 ⁰ /566 ⁰ C	39.91	0.35	1.31
5.	246	566 ⁰ /593 ⁰ C	40.24	0.33	1.64
6.	246	600 ⁰ /600 ⁰ C	40.56	0.32	1.96

Keeping in view the world experience it is recommended that the pressure of 246-250 kg/cm² may be adopted at the turbine inlet. The selection of temperatures may also be made with a view to derive maximum efficiency gains at the same time preventing large scale shift to advance materials on account of considerations of cost and provenness. The P91/T91 materials were being used in our 500 MW units are reported to be suitable for upto 600 °C with pressures of 300 ata. It is thus recommended that higher main steam/reheat temperature of 566°C/ 593 °C may be adopted for deriving maximum efficiency gains from higher size units.

4.6 Cost Economics

The economies of scale in general is likely to have lower specific cost (per MW basis) for higher size units.

However, introduction of any new technology is associated with certain inherent cost on account of technology procurement, its adaptation/indigenisation, creation of additional facilities for manufacturing and transport infrastructure etc.

These costs would however progressively reduce with increased indigenisation. BHEL have projected an import content versus indigenous content of 90:10 for turbine for first unit to be progressively lowered to 20:80 for 4th unit. For generator the corresponding ratios are 95:05 and 100:0.

The first few units are also likely to entail higher implementation time and also longer stabilization period due to our coal quality for attaining requisite proficiency from the operating staff and performance. Similarly, the maintenance schedules/outages would also take sometime to reach their optimum levels. These issues are however intrinsic to any technology transfer and would remain same irrespective of the unit sizes/technology chosen. However, they would entail additional costs to the utility/suppliers.

4.7 Indigenous capacity building

The present Indian manufacturing capability is only upto the unit of 500 MW size and BHEL has entered into collaboration with Siemens and Babcock Borsig power for super-critical turbine generators and boilers for higher size units. BHEL are also tying up with M/s Alstom due to financial problems of M/s Babcock Borsig Power. For long-term sustainability, it is imperative that unit size chosen be manufactured indigenously to reduce the cost and also time period for installation and also timely availability of spares etc. The committee has, therefore, taken stock of present indigenous manufacturing capability and also identified strategy for requisite capacity building so as to achieve future indigenous capacity for manufacturing, installation/erection and subsequent maintenance/supply of spares etc. for the unit size proposed .

BHEL during their presentation to the committee, have informed that they have an ongoing collaboration with Siemens for turbo-generators which covers all unit sizes upto 1000 MW including supercritical units. M/s. Siemens have technology for extraction from HP turbine for feed water heating though only a few numbers of such units have been supplied. The HP, IP & LP modules proposed for 800 MW units are fully proven and operational. One no. H30-100-M2 module for HP turbine, M30-100-M2 module for IP turbine and 2 nos N30-4x8 LP turbine

modules are proposed to be used for 800 MW units. The Boiler feed pumps have to be imported initially. Also, in view of very large motor size for start up motor driven BFP of 50% capacity, the same would have to be reduced to 30%.

The 800 MW units are expected to have 10 nos. XRP1203 mills which can be manufactured indigenously by BHEL or can be outsourced initially if required. As the radial I.D. fan for such large unit would be of excessively large dimension, variable pitch axial fans would have to be installed and M/s. BHEL are already in the process of making a collaboration arrangements with M/s. TLT fans Germany for the manufacturer of these fans. The ESP can be manufactured and supplied indigenously by BHEL without any constraint.

4.8 Environmental benefits of Higher Size Units

As mentioned above, higher size units of 800-1000 MW will accelerate pace of capacity addition. Further, keeping with the objective of lesser impact on environment due to coal capacity addition, adoption of supercritical technology and higher parameters (566 °C/593 °C) will result in higher efficiency leading to lower CO₂ & SO_x emissions per unit of electricity generated. Emissions of other pollutants like NO_x & SPM would also reduce with adoption of latest technologies of low NO_x burners, staged combustion, efficient ESPs etc.

Higher efficiency, besides leading to corresponding savings in coal consumption, would also lead to lower ash generation. The land requirement for ash dump areas would also correspondingly reduce and there would be reduction in auxiliary power consumption.

4.9 Other Issues

Apart from the indigenous manufacturing capability of the main plant equipment, several other areas would need attention for induction of large sized units in the Indian power sector. Some of these include strengthening of transport system, erection and operational capability, indigenous capability of manufacture of auxiliary systems, manpower training etc.

The higher size units are likely to have higher overall weights of individual components and special transport arrangements would have to be developed. The heaviest components for 800 MW units would be generator stator weighing about 386 tones and would need to be transported by road for which adequate strengthening of roads /culverts etc. may be required. Designs for transportation of generator stator upto 750 MW have been finalized & orders could be placed on railways if required. Availability of spares and service/maintenance support is very crucial especially during initial years and these aspects should be properly taken care.

It would be desirable to use deshaled /washed /blended coals of consistent quality for optimal performance of higher size units. This would also help reduce teething problems due to high ash indigenous coal and thus result in early stabilisation of higher size units.

4.10 Strategy for induction

The strategy for gradual and systematic induction of large sized units in the Indian grid will have to be adopted to maximize the benefits and reduce problem areas. Specific regions/states/utilities where these units could be inducted initially would have to be identified. Possible induction in coastal areas with imported coal and such other aspects may also have to be considered.

As brought out in para 4.6, the first few higher size units are likely to involve higher cost on account of new technologies to be procured, higher import content, technology adoption issues and creation of additional facilities. The operating utilities would also entail higher cost due to higher implementation time/stabilisation periods and higher time lag for achieving requisite performance for initial few units. A way would have to be found for absorbing the above cost. M/s BHEL have suggested that the higher size unit should be taken as a national project and technology should be inducted through BHEL. It is felt that for successful implementation of large size units of supercritical parameters on sustained basis, it is essential to have a rapid technology adaptation and complete

indigenisation as fast as possible with a view to ensure uninterrupted and reliable supply of equipment/spares and to also develop requisite O&M capability. It is therefore suggested that 8-10 nos. units of higher size are ordered in bulk for installation at 2-3 stations of NTPC or well run SEBs like MSEB, APGENCO etc. With a view to partially offset the higher cost of technology absorption, the government may provide financial support to BHEL and the implementing utilities for the first few units with a view to contain tariff to realistic levels. It is further proposed to form a group consisting of CEA, BHEL, NTPC and some major utilities and a foreign consultant to evolve basic design features of supercritical units optimized for Indian conditions. This would also help Indian manufacturers in selecting technology partners/collaborators.

5. Conclusions

1. In view of the ambitious power programme envisaged over the next two decades it is essential to significantly increase the pace of capacity addition. A thermal capacity addition would have to increase to about 6000-7000 MW per year to achieve the targeted capacity additions.
2. Sufficient operational experience have been gained over the years in operation of 500MW units and the performance of 500 MW units have been much better than the other capacity groups of smaller sizes. With the operation of these units, sufficient expertise has been developed in operation of turbo-BFPs, assisted circulation system, once through boiler designs (sub-critical), stringent water chemistry, condensate polishing etc. thus enabling environment is existing in the country for adoption of super critical units of higher size from 800 to 1000 MW.
3. There has been sufficient strengthening of the regional grids over the last decade. The Western and Eastern grids are already operating in synchronism and the Northern grid is also likely to be connected shortly. With such large grid sizes which are comparable to some of the largest grids in developed countries, accommodating large size units does not pose any constraint and any unit size upto 1000 MW can be incorporated in the grids.
4. With the progressive increase in installed capacity, higher share of thermal generation and large peak to off peak ratios, backing down, and cyclic operation of thermal units would become imminent. Super critical thermal units offer better operational profile in such an environment.
5. A large number of supercritical units of 500-1300 MW are operational worldwide and the reliability and availability of these units is stated to be at par with the sub-critical units indicating the maturity of the technology.

6. BHEL is fully prepared to take up manufacture of supercritical units upto 1000 MW size and have technology arrangements in place. The present capacity of BHEL to supply thermal units of 4500 MW per year could be increased to about 6000 MW per year if sufficient orders are available.
7. **In view of the above, the committee recommends that the next higher units size adopted in the country should be from 800 to 1000 MW. The steam parameters of 246 - 250 kg/cm², and higher steam temperatures of 568°C to 593 °C may be adopted depending upon site specific techno-economics for deriving maximum efficiency gains from higher size units .**
8. In order to really achieve the benefits of higher efficiency of super critical units, it is essential that the operating practices and skills of the utility are considerably improved to enable achieve design performance of these units.
9. Considering the huge financial repercussions of sub-optimal performance of large size units, the committee recommends that stringent quality control measures are taken at each stage and reliable and proven technologies are adopted with a view to achieve quick stabilization of the higher size units.
10. **Effort should be made to rapidly indigenize the manufacture of large unit sizes adopted. With this in view the committee recommends that 8-10 nos. of higher size units are ordered in bulk with a view to achieve rapid indigenisation and also lower the project cost.**
11. It is proposed to form a group consisting of CEA, BHEL, NTPC and some major utilities and a foreign consultant to evolve basic design features of supercritical units optimized for Indian conditions. This would also help Indian manufacturers in selecting technology partners/collaborators

12. The turbine designs should be fully optimized with respect to our ambient temperature conditions so as to achieve best possible efficiency for the higher size units.
13. Adequate measures need to be taken to supply coal of consistent quality & free of shales & extraneous matter for optimal performance of higher size units.
14. Availability of spares and service/maintenance support is very crucial especially during initial years and these aspects should be properly taken care of.

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