ENERGY CONSERVATION ASPECTS IN INDIAN THERMAL POWER STATIONS BY TECHNOLOGICAL INNOVATIONS: EXPERIENCE AND PROSPECTIVES

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Abstract—The work presents the analysis of the concentrated efforts put up by Indian technologists for harnessing maximum energy from thermal power stations (TPS). The prime objectives have been to extract maximum energy from coal. All the controllable losses should be minimized in all operations and systems. Model outlines and practices followed by energy efficient power stations have been summarized. Measures to consume the least possible steam, materials, and petroleum products have been studied in detail. The role of condenser vacuum, excess air, all types of auxiliary (works) power, and an energy audit have been investigated in maximizing power generation. Approaches either to renovate, repair or retrofit or replace the ageing components having poor economic performance with modern technologies have been illustrated. The present system and technologies would be obsolete and economically and energy-wise highly inefficient by the turn of the century. Thus developed/currently advanced and futuristic (under advanced stages of development) technologies have been listed for applications now or later. In spite of spending 20% of total planned expenditure since 1950 on power, the significance of energy conservation for bridging the energy gap should remain on the top of the Indian energy alternatives list, according to the conclusions of the present study.

NOMENCLATURE

BFP Boiler feed pump
Encon Energy conservation
FD Fan Forced draft fan
HR Heat rate
ID Fan Induced draft fan
PA Fan Primary air fan
PSE Power station engineer
O & M Operation and maintenance
TPS Thermal power station

INTRODUCTION

Gulf oil shocks of 1973, 1979 and the Gulf war in 1990 exposed that the enormous waste of energy and materials have gone hand-in-hand with economic waste, ecological and environmental degradation. This gave rise to sudden significance of energy-management strategies leading to diversifications, substitutions and innovations in energy conservation (Encon). A significant part of this realization penetrated into the minds of Indian thermal power station (TPS) personnel too. With the installed thermal generation capacity of about 650,000 MW as at July 1992, having 8–18% of auxiliary consumption in various TPS, a mere reduction by 10% will amount to generation of 650 MW. This is equivalent to a saving of Rs. 1950 crores in capital investment alone. Further thermal efficiency tests indicate how much of the heat energy supplied to the power station is efficiently converted into electrical energy by safeguarding equipment and the environment. However, energy conservation studies presented in this paper reveal how much more would have been possible to generate through application of administrative (management), technological (Operation & Maintenance) energy audit, life extension/renovations or new/high technology measures. The data and information has been compiled by technical study visits by I. P. S. Paul in 15 different power plants located near Thermal Training Institutes at Badarpur (New Delhi 1987–1989),
Durgapur (West Bengal 1985–1986), Neyveli (Tamil Nadu 1989–1991) and at Nagpur (Maharashtra, 1991 to date). It is believed by the authors that there is scope for energy conservation of 10–15% in each plant. Basic procedures for implementation of Encon in TPSs is illustrated in Fig. 1.

**ENCON THROUGH BASIC DESIGN OF ENGINEERING CONCEPTS**

In the design stage it is important to create a life-long impact for higher efficiency and optimization of parameters for Encon. Compact and systematic layout brings different kinds of lasting benefits.

Adoption of main steam parameters of 150 atm and 537/537°C for 210 MW and 170 atm and 537/537°C for 500 MW is almost standardized. Thus there is an improvement of pressure from 130 to 150 atm, heat rate improvement by 40 kcal kWh⁻¹ (i.e. ca 2%). Further, by going from 150 to 170 atm heat rate improvements from 20 to 22 kcal kWh⁻¹ (i.e. 1%) have been achieved. In Section 11 of the paper various advanced technologies have been enumerated which also call for improvements at the beginning of the design stage itself. Study of old and new thermal units in India for changes to turbine heat rate, boiler efficiency and unit heat rate are given in Table 1.

**COMPONENTS CONSTITUTING ENERGY IN TPS**

The paper studies the following direct and indirect forms of energy in action in TPS.

1. Direct forms of energy are (i) coal or lignite, (ii) light diesel oil, high-speed diesel or petrol, furnace oil/lubricants/greases, (iii) works (auxiliary) power.

2. Indirect forms include (i) demineralized water, treated water or raw water, (ii) steam both high and low pressure, (iii) residual heat in ash, stack or hot water, (iv) compressed air, (v) materials.

We shall now discuss Indian techniques and technologies for the saving of energy in all these components of the plant.

**Table 1. Comparison of old and new plants’ turbine, unit heat rates and boiler efficiency**

<table>
<thead>
<tr>
<th>Area</th>
<th>Unit</th>
<th>Design Values</th>
<th>Old station</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbine heat rate (THR)</td>
<td>kcal/kWh⁻¹</td>
<td>1975</td>
<td>2250</td>
<td>275</td>
</tr>
<tr>
<td>Boiler efficiency (BE)</td>
<td>%</td>
<td>80%</td>
<td>86%</td>
<td>6</td>
</tr>
<tr>
<td>Unit heat rate (UHR)</td>
<td>kcal/kWh⁻¹</td>
<td>2300</td>
<td>2600</td>
<td>300</td>
</tr>
</tbody>
</table>
COAL AND LIGNITE CONSERVATION

During one author's (IPSPr) posting at Neyveli in South India in 1991, a study conducted on its 30 MW, 100 MW and 210 MW sets revealed that 1 kg of lignite (brown coal) which had a dormant heat energy of 2450 kcal is equivalent to 2.849 kWh of electrical energy. After undergoing energy conversion the electricity reaches the HV transmission system as only 0.812 kWh. If we account for transmission and distribution losses (T&D losses) this energy reaches the energy consumers as only 0.65 kWh.

Further study identified that in terms of the quantity of brown coal, from 1 kg, 119 g is spent in boiler losses, 530 g in condenser losses, just 5 g in generator losses, 32 g in energy spent in auxiliary consumption. Only 3 g are attributable to transformer losses. The 285 g account for the above stated 0.812 kWh of energy delivered to the transmission system.

It would thus be appreciated that 320 g out of every kg of lignite contributes to the gross generation at the generator terminals. It could be of interest to know that if 1% of this quantity of lignite is conserved for additional generation of power, the economic gain due to a saving of fuel amounts to Rs. 27,694 per year.

Coal or lignite conservation is the prime objective of Indian engineers as it is the sole and basic form of energy. All engineering fundamentals and innovative applications lead to the aim of up to 5% of black or brown “diamonds” conservation which are discussed below.

Optimum operations

Optimum operational efficiency can be brought about by the following: (i) Proper air and fuel distribution, temperature and mixing with oxygen (air) and adequate fuel quantity and velocity, i.e. 3 Ts (time, temperature and turbulence) help swings. (ii) Use of low-excess air burners to save in NOx and unburnt oxygen and optimum heat recovery in the air preheater and economizer, as a 4.5°C rise in flue gas temperature would reduce boiler efficiency by about 1%.

Unburnt carbon loss in flue gas and bottom ash should be minimized by a stipulated fineness of coal/lignite, which is not to be off-set by “coal mill and fan power” consumption.

Reduce carpet loss at the coal store, its burning in the coal yard and distribution or spreading in fields during transportation, by air or wind velocities.

Radiation and unaccounted losses like casing radiation, sensible heat in refuse, ash hopper evaporation and bottom water seal evaporation should be minimized.

Fire prevention measures in the coal-handling plant, coal-storage area, water quenching, resthifting and hard pressing would also help in conservation.

CONSERVATION OF STEAM

Soot blowing

About 1% of superheated steam having a high enthalpy and 0.62% of the heat content is used for soot blowing, needing about 0.25% of extra heat to make good the loss. The total loss is thus 0.87%. Thus it would pay to plan soot blowing frequency keeping boiler availability in mind to recover heat by cleaner condenser tubes.

Blow-down

Here about 1% blow-down carries a heat content of about 0.17% of heat added, needing 0.25% to make good the loss. The total loss is about 0.42%. However, it is not a total loss, as we have to carry blow-down to meet requirements either to continuously or intermittently remove concentration impurities. Blow-down recovery is desirable and is explained in Fig. 2.

Other steam conservation measures

The impure steam containing silica chloride leads to deposits on turbine blades. This loss is up to 5% in efficiency and a reduction of 20% output. Even an increase in surface roughness on blades of 10 μm will cause a 10% reduction of HR on a 210 MW turbine.

Boiler tube failures also happen partly because of impure steam. Abrupt shutdown wastes a lot of heat energy in restarts.
Prompt arresting of steam leakage from pipelines, valve glands, and steam traps is recommended. Proper insulation and refractory around furnace, valve glands, pipes, walls, and steam chest also preserves heat to reduce fuel consumption.

Effective use of high/low pressure-feed heaters is important for a higher efficiency of plant and thus savings in fuel. Turbine heat rate (THR) is increased by 2–3% by using an HP heater in 200–210 MW units. When heater performance suffers, the terminal temperature difference (TTD) would increase and outlet feed temperature will also increase. The deficiency from one heater will be met by the next higher heater drawing more steam from a higher stage. This reduces work done in the turbine stage. The falling efficiency will be of the order of 0.03% for each degree of TTD rise. HP heater bypass valve passing and feed-heater drains not cascading properly should be attended to. The efficiency loss for LPH and HPH being out of service is 0.5% and 1.3% respectively per heater.

Steam-driven BFPs are 1.6% more energy efficient when compared with electrical-motor-driven BFPs in 500 MW sets. Thus a lot of steam is saved.

**SLIDING-PRESSURE OPERATION**

Base-load operation has been opted for in most thermal stations in India. However, in future these plants may be required to operate under part-loads, and also under low-load system conditions. For higher part-load efficiencies, systems and equipment have been designed for a sliding-pressure mode of operation. In this mode of operation throttle losses at part-load are eliminated, and power consumption goes down. Further, this advantage has been fully realized in steam-driven BFPs. Thus it has been possible to improve the heat rate to the tune of 15 kcal kWh⁻¹ at 80% and 30 kcal kWh⁻¹ at 60% load for 500 MW units.
CONSERVATION OF FURNACE OIL

This is linked to: (a) the quality of coal in terms of moisture, calorific value and volatile contents, (b) part-load operation, (c) frequent outages leading to fresh starts, (d) equipment deficiencies (design/erection, O & M), (e) grid-network condition, (studies conducted have uncovered Encon application areas in a majority of the stations), (f) stopping leakage and extra topping may be also helpful.

Oil spillage is to be avoided at all costs as it is a fire hazard as well as wasteful.

Viscosity of the oil at the burner tip should be 20 Engler in order to have better atomization. Hence, each consignment of oil should be tested for its viscosity characteristic with respect to temperature and this must be practised in operation.

Use of reliable flame scanners working on fibre optic principles. Improved oil burners should be used for better combustion.

Vanadium in oil forms yellow deposits at high-temperature zones and affects heat transfer. They are very difficult to remove, but additives are now available to remove these anti-heat transfer deposits. Vanadium deposits, if soaked in alkaline solution for a considerable duration, can be removed by applying high-pressure jets.

With improper combustion, air heater fire is a common phenomenon. Hence, it is advisable to use suitable techniques to detect oil carry-over to air preheaters in order to prevent air heater fires. Proper fire-sensing devices in the air preheater and fire-protection devices are necessary in case of oil fuel usage in the air preheater area.

Steam atomized oil tips are better than pressure atomized oil tips. The only precaution that has to be adopted is that steam pressure should always be maintained as recommended by the boiler manufacturer.

Proper control of the shape of the flame is necessary by way of proper design of the diffuser and air adjustments.

Improper flame shape can result in flame impingement and tube failures.

ROLE OF EXCESS AIR

The causes of excess gas quantity are the following:

(a) Air leakage through man holes, peepholes and the bottom seal.
(b) Air preheater seal leakage.
(c) Air dampers passing for the shutdown.
(d) Uneven distribution of combustion air.
(e) Inaccurate air adjustments on the basis of unrepresentative samples and inaccurate analysis.
(f) High-moisture coal evolves lot of steam which has to be handled, apart from products of combustion.

All these factors in turn increase fan power consumption and thus have a deteriorating effect on load output. It has been estimated that in the majority of the Indian boilers 20% excess air reduces boiler efficiency by 1% (see Fig. 3 and Table 2).

The infiltration of air in the combustion zone lowers furnace temperature. This reduces the magnitude of radiative heat transfer, and accordingly increases the convective heat transfer.

The extent of radiative heat transfer depends upon the volume of concentration of water and CO₂ in the furnace. Moisture contents are high during the rainy season and cause secondary variations in flame emissivity and thus changes the magnitude of radiant heat transfer. Those metals in the radiant zone are likely to be overheated. Attention is also needed to monitor the oxygen concentration in flue gases.

Increased air ingress causes an increase in the volume of flow and thus the velocity of flue gas. This further causes an increased rate of erosion of economizer tubes and ID fan impellers.

The minimum loss occurs when the carbon monoxide (CO) content in flue gas is 200 ppm and volatile matter in coal is below 18% (by weight on air-dried sample). A 20°C rise in flue gas outlet at air preheater gas temperature contributes to a reduction in boiler efficiency by 1%. However,
a 1% decrease in CO₂ will increase the loss by 0.01%. Indian PC boilers are expected to operate with 25 and 30% excess air at economizer and air-preheater outlets respectively.

Corrective measures. Corrective measures to limit the excess air within optimum limits to be taken are suggested as follows: (i) Regulation of fineness of coal by adjusting classifier vanes, tension of the spring on the grinding rolls or ball, charging, and timely replacement of worn-out parts in coal mills. (ii) Prevention of leakage of air into the furnace due to various causes as described above by better O&M practices.

SAVINGS THROUGH AUXILIARY (WORKS) POWER

It has been found that auxiliary power consumed on a percentage basis would be high, when the generation is on the lower side (Fig. 4). Thus it can be reduced simply by generating at maximum power. Low-load operation can be avoided as the efficiency of the main equipment and associated auxiliaries undergo variations, vibrations increase (Fig. 5). As a result of discussions/or review meetings while on technical study visits to 15 TPSs in various parts of India, the following action-oriented dimensions and directions have emerged:

No second auxiliary should be allowed to be in service unless it is absolutely necessary with respect to (a) load requirements, (b) constraints in the system, (c) manufacturers' instructions.

Coal mills appropriate in number should be run by reviewing the requirements of steam/unit output, furnace temperature, and the condition of the mills. They should be monitored with change in load in every shift.

Coal/lignite should be neither over- nor under-ground, as this consumes power and affects boiler performance and unburnt carbon loss.

<table>
<thead>
<tr>
<th>Fuel type</th>
<th>Firing method</th>
<th>Optimum excess air (%)</th>
<th>Equivalent O₂ (by volume)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural gas</td>
<td>—</td>
<td>5-10</td>
<td>1.2</td>
</tr>
<tr>
<td>Propane</td>
<td>—</td>
<td>5-10</td>
<td>1.2</td>
</tr>
<tr>
<td>Coke oven gas</td>
<td>—</td>
<td>5-10</td>
<td>1.2</td>
</tr>
<tr>
<td>No. 2 Oil</td>
<td>Steam-atomizing</td>
<td>10-15</td>
<td>2.3</td>
</tr>
<tr>
<td>No. 6 Oil</td>
<td>Steam-atomizing</td>
<td>10-15</td>
<td>2.3</td>
</tr>
<tr>
<td>Coal</td>
<td>Pulverized</td>
<td>15-20</td>
<td>3.3-5</td>
</tr>
<tr>
<td>Coal</td>
<td>Stoker</td>
<td>20-30</td>
<td>3.5-5</td>
</tr>
</tbody>
</table>
Other factors influencing the power consumption in mills include (a) grindability index, (b) moisture in coal/lignite, (c) the number of mills in operation with respect to load at the same time.

The design considerations too have played a role in power consumption and performance of mills. It is customary for manufacturers the world-over to give at least 50% extra mill capacity. Thus, for a 200 MW boiler, the design coal requirement is 120 tonne h\(^{-1}\). For a specified coal of say 4000 kcal kg\(^{-1}\) it is possible that a designer would select an XRP 803 mill having 39 tonne h\(^{-1}\) as base capacity. Six mills will be selected for this contract, while four will meet the load requirements, at an expected delivery of 30 tonne h\(^{-1}\), whereas its base capacity is 39 tonne h\(^{-1}\). The ratio of design grinding capacity to base load is known as the mill load factor, and in this case it is 76.9%. Apart from two additional mills, each working mill has a reserve capacity of 23.1%.

Pumps liable to air accumulation should be vented regularly, as trapped air increases power consumption. In general the better the vacuum, the better the heat consumption for a given load. However, when we look into a vacuum vs heat input curve (Fig. 6), we find that going beyond a certain minimum (25 bar in this case) will actually deteriorate the situation. The works power of the circulating water-pump is offset by the efficiency gained, and thus optimal vacuum will be created in the condenser.

*Selection of motor drives.* Techno-economic studies reveal that for units in excess of 200/210 MW, steam-turbine drives rather than power drives in BFP prove to be both energy-efficient and variable in speed. There is no need for additional equipment, such as hydraulic couplings, and thus coupling losses are eliminated.

For adverse conditions of operation large margins are provided by designers. In order to fit the drive-rating into standard drive sizes, these margins are increased further. Thus the drives normally operate at 60–70% of their ratings. In India now, suppliers and manufacturers of the plants are
to design equipment/systems for optimum auxiliary consumption. Buyers add evaluation factors for auxiliary power consumption in the tender specifications. Bidders are thus evaluated for auxiliary consumption quoted and guaranteed. Thus, during design, planning and tendering, auxiliary consumption should be attended to.

With variable-frequency drives and solid-state energy controllers, the power consumption can be reduced. With the controller, the motor terminal voltage is controlled to operate the motor with minimum loss at all loads. Annual savings are 3.7% of the motor capacity.

Reduce unnecessary illumination lighting and ventilation and use air-conditioning time switches, clean tubes and bulbs and their reflectors. Use tube lights rather than bulbs, and introduce electronic ballast as a replacement for electromagnetic, chokes, etc.

Percentage power goes up as turbo alternator (T/A) load decreases.

**Optimization efforts.** As a management exercise after conducting energy audits, monthly targets should be set for reducing all types of energy use. Persons of all disciplines and grades should be involved. However, the real cost of excess works power can vary considerably according to whether (a) it is a total loss, or (b) it merely replaces other energy sources or is offset by consequential efficiency savings.

Total loss of excess works power consists of (i) 1D fan, (ii) station services, (iii) ash and dust plants.

Works power which partially replaces other heat sources are (i) electric feed pumps, (ii) condensate pumps, (iii) FD or PA fans and (iv) milling plants.

| Table 3. Study of heat loss of 210 MW boiler and other losses and their financial analysis |
|-----------------------------------------------|----------------|----------------|
| Cause                                         | Heat loss kcal kWh⁻¹ | Financial loss Rs. kWh⁻¹ |
| 1. Losses on account of coal (due to sampling, weight, excessive foreign material, etc.) | 50-200 | 1-4 |
| 2. Improper combustion (O₂, high unburnt carbon) | 200-400 | 4-8 |
| 3. Vacuum poor                                 | 100-300 | 2-6 |
| 4. Parameter violations (steam power low, feed water temperature low, excessive temperature in HR steam) | 50-100 | 1-2 |
| 5. Make-up high (4-8% against 2%)              | 50-100 | 1-2 |
| 6. Auxiliary consumption (12-14% against normal 10%) | 50-100 | 1-2 |
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Table 4. Quantification of financial implications due to various losses in Indian TPSs

<table>
<thead>
<tr>
<th>Title</th>
<th>Value</th>
<th>Money loss in Rs. LWh⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Increase in condenser back pressure</td>
<td>100 MMWC</td>
<td>1.2</td>
</tr>
<tr>
<td>2. Increase in make-up water consumption</td>
<td>1%</td>
<td>0.21</td>
</tr>
<tr>
<td>3. Increase in excess-air</td>
<td>1%</td>
<td>0.012</td>
</tr>
<tr>
<td>4. Increase in heat rate</td>
<td>100 kcal</td>
<td>1.2</td>
</tr>
<tr>
<td>5. Increase in specific oil</td>
<td>1 ml</td>
<td>0.4</td>
</tr>
<tr>
<td>6. Increase in stack temperature</td>
<td>100°C</td>
<td>0.15</td>
</tr>
<tr>
<td>7. Increase in S/H temperature</td>
<td>15°C</td>
<td>0.1</td>
</tr>
<tr>
<td>8. HP Heater not charged</td>
<td>—</td>
<td>0.45</td>
</tr>
</tbody>
</table>

The efficiency of the boiler and turbine have a marked effect on auxiliary power consumption. Heat consumption reduces with an increase in boiler efficiency.

Start-up and shut-down losses. There is a good relationship between energy consumed and time taken for starting. By observing engineering limits, a quick start is the most energy-efficient. Open valve boiler start-up is recommended as this saves half of the cold start-up costs.

Analysis of the study of heat losses of a 210 MW boiler and other losses and their financial analysis are given in Table 3. The quantification of the financial implications due to various losses are given in Table 4.

THE ROLE IN ENCON OF METALLURGICAL DEGRADATION AND FAILURES

The high rates of failures of boiler tubes, bearings, mill parts, pipes, pumps and fan impellers, contribute both to TPS inefficiency and indirectly premature loss of energy employed to manufacture them. Indian coal, with its highly erosive and abrasive strength and the presence of unsuitable materials, adds to inefficient utilization of materials wherever it comes in contact with them. Investigations in TPS have led to the monitoring of the following measures by PSEs with the assistance of instrumentation and operational data:

- Temperature of metal and steam in different parts of the boiler and turbine.
- Fluid pressure and pressure drops.
- Ash handling in different parts of the boiler, and later in disposal pipes, etc.
- Oxygen content at different levels and locations.
- Emissivity of flame, and factors such as (a) moisture, (b) nature of contents of volatile matter, (c) nature of mineral constituents of ash, with combustion kinetics and coal pulverization.
- Temperature of flue gases in different locations in boiler and chimney.
- Use of chemicals, consumables, lubricants, spares are all susceptible to Encon measures by effective inventory management, e.g. by fixing minimum and maximum re-ordering levels.

ENERGY AUDIT: AN INTEGRAL STEP IN THE MANAGEMENT PROCESS

Like accounts audits and medical check-ups and reports this essential tool generates the following technical and managerial action points:

The information database compiled should contain a review of maintenance schedules, renovations and modernization activities.

It should also contain information to enable identification of potential Encon areas, the setting-up of standards, the norms for energy use, and for reviewing policies and specific strategies for Encon.

It should also cover identification of training needs of power-plant personnel, with respect to specific equipment and systems of a particular plant.

LIFE EXTENSION AS ENCON SOURCE

India has investigated the necessity of renovation and modernization of about 80 TPSs in two phases (1985–1990 and 1990–1995) having 365 units totalling 33585 MW capacity. The technological and financial analysis revealed that every third TPS needs Life Assessment Studies (LAS) and
implementation of a Life Extension Programme (LEP). The "old becomes gold" in one fourth the cost and time; with the rectification of generic defects by retrofitting of advanced or newer technologies. The studies on the extent of damage due to ageing of the components helps in the renovation of the various components. Since the efficiency of the individual equipment is interdependent and interrelated with other components, the life-extension measures help the technologically updating of the deteriorated or old-technology components. Thus, directly and indirectly, life extension contributes to Encon and thus higher generation. This has given the additional benefit of 15,000 MU, equivalent to 3000 MW.

UPDATING WITH DEVELOPED AND FUTURISTIC R & D OF ENCON TECHNOLOGIES IN TPS

The controllable and uncontrollable losses and failure analysis of outages have given rise to some Encon ideas for R & D approaches. Some of the current or advanced design and development Encon technologies are listed in two parts below:

Developed Encon technologies

(a) Once-through (drumless) boiler having tube mills with critical and supercritical pressure to suit highly abrasive coal and fast load response.

(b) Fluidized (pressurized, bubbling, atmospheric and circulating) combustion boilers for lower NOx/Sox emission, low-grade coal/washery rejects burning, dry ash disposal and quicker start-up or shut-down.

(c) Tower-type boilers for highly abrasive ash contents and avoiding boiler tube failures as pressure parts are located above the furnace.

(d) Direct ignition of pulverized coal (DIPC) boilers.

(e) Brushless exciters, belt masters in belting systems, controller of ESP, microprocessor-based relays, optical fibre cable for protection and control, variable frequency drives.

(f) High-efficiency combined cycle plants, (CCPP) cogeneration (Cogen) power plant, integrated coal gasification combined cycle plants (IGCC), dry-ash handling and disposal to reduce land or water requirements and pollution to surrounding waterways. India may shortly form an Ash Utilization Corporation Ltd effectively to utilize enormous quantity of ash of TPS and other utilities.

(g) Advanced and commercially proven electronics, computer and value-engineering applications. Such examples are electro-hydraulic and turbine stress-evaluation systems, Automatic Turbine Runup System (ATRS), Digital Distributed Control (DDC) system and monitoring, optimized soot blowing, through intelligent soot blowing systems, intelligent alarm management, self-tuning controls and diagnostic analysis, a self-monitoring system for detecting system failure, determination of the cleanliness factor of condenser tubes, vibration isolation system, using helical spring and clamper for turbine, BFP crusher, ID and PA fans.

Futuristic approaches

(a) Alternative—economic raw material input.

(b) Higher process (temperature-pressure) efficiency.

(c) Elimination and reduction of energy use.

(d) Even more improved combustion technologies and waste heat recovery.

(e) Even lower air burners for oil, coal and gas.

(f) Low-quality energy substitutions, and newer applications based on the Second Law of Thermodynamics, etc.

The payback through savings in auxiliary consumption normally far outweighs the extra capital expenditure.

CONCLUSIONS AND DISCUSSIONS FOR A POWERFUL TOMORROW

Encon is energy-intensive sub-plants by effective O & M optimization measures, application of newer or advanced technologies which would be more profitable; both in short- and long-term
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perspectives, some of these measures are well identified, sensitive to energy savings and can even deliver prompt dividends.

Encon activities can not deliver the desired results when implemented in isolation, because of poor results in investment ratio for most cases in the industry.

Specific action-orientated strategies yield excellent results when their benefits are shared by plant and corporate personnel as well as the organization. Thus, relevance by involvement is realized, percolated by conscious acceptance of the challenge. The benefit is enormous.

The plant at times is unnecessarily loaded with stand-by and derated equipment, which are forced to "drag their feet" all through their operating life. Its renovation with changes, developments or latest engineering retrofits would save an immense amount of energy.

A fresh look and unbiased judgment is a must when designing TPS for energy-efficient and economic performance.

Sensitivity analysis shows that, on the basis of performance parameters optimized for Encon measures, overall efficiency of the entire plant will improve considerably. The success of Encon primarily depends upon management decisions rather than technology alone.

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Any views expressed are those of the authors and not necessarily those of the working organizations.

REFERENCES

3. Consultations with Neyveli TS-I/TS-II (NLC), Tuticorin and Mettur (TNEB), Kozadi and Khapeshkeda (MSEB), Thermal Power Station engineers, during presentations and technical study visits in 1990-92.