Ventilation Systems for Thermal Power Plants

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Raichur thermal power plant

Introduction

The power sector in India has made significant progress since Independence. In 1947, the country had a power generating capacity of just 1,362 MW. Most of these power plants were managed by private utility companies. Notable amongst them, and still in existence, is Calcutta Electric Supply Corporation. Power was available only in a few urban centres; rural areas and villages did not have electricity.

In August 2011, India's installed power generation capacity stood at 1,81,558 MW, out of which thermal power plants account for 1,18,630 MW, followed by hydro power plants with a capacity of 39,089 MW, renewable energy sources with a capacity of 18,918 MW and the remaining 4,921 MW coming from nuclear energy. Within the thermal power plants, coal-based power plants have an installed capacity of 99,724 MW, gas-based 17,706 MW and oil-based 1,200 MW.

Per capita electricity consumption in India is just about 704 kWhr compared to 14000 kWhr in USA, 8200 kWhr in Japan, 8100 kWhr in France and 1475 kWhr in China. We need much more power as we set up more industries, as we reach power to more people, and as our people get financially stronger. The total demand for electricity in India is expected to cross 9,50,000 MW by 2030.

Thermal power plant sizes are growing bigger and bigger – from super thermal to mega to ultra mega projects. Project owners' band has also widened from state electricity boards and government agencies to private owners. Captive power projects in the government and private sectors are now quite common.

Ventilation systems in power projects have also travelled miles during this period. They have changed from natural ventilation using some louvers and roof monitors or roof exhaust fans to evaporative cooling and pressurized ventilation. This is resulting in cleaner and cooler environment for both men and machines.

This article elaborates the evolution of ventilation systems in thermal power projects in the last six decades.

What is Ventilation?

Ventilation, in simple terms, can be described as air circulation and removal of stale, overheated and contaminated air, and supply and distribution of fresh air in amounts necessary to provide the desired conditions for the occupants and equipment in a closed space to improve productivity. This creates an environment which stimulates the occupants and equipment to higher efficiency.

There are various types of ventilation systems:

Natural Ventilation

This is the oldest of all types of ventilation, and is totally dependent on

About the Author

Prabir Sen completed his graduation and masters in mechanical engineering from REC (now NIT) Durgapur, and has over 39 years of experience in the HVAC industry. Prior to his present assignment, he worked in Development Consultants Ltd., Voltas Ltd., The Kuljian Corporation, USA and Egypt and Samsung Heavy Industries, South Korea.

He is a member of ISHRAE and ASHRAE, and a past president of the Association of Ventilation Engineers. He has over a dozen publications to his credit and has presented papers in a number of seminars.

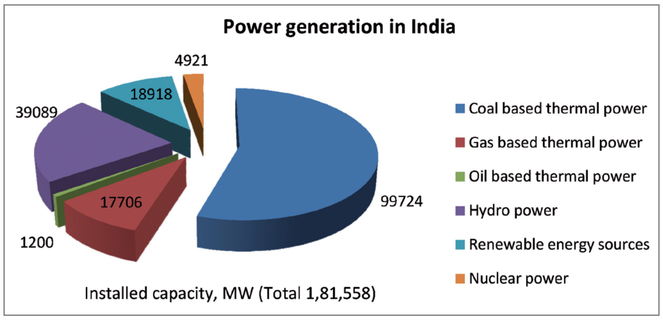

Figure 1: Power generation capacity in India by type of power plant

basic laws of nature. A temperature difference between outside and inside air will create a natural draft, forcing air to flow through the building. In most industrial buildings with this type of ventilation, the inside temperature is higher than the outside temperature and thus, outside air will flow into the building through some openings provided, take away some heat, and move out through some other openings provided on the top of the building. Air moves in and out of buildings at varying rates depending upon a number of factors relating to both the construction of the building and the local meteorological and seasonal conditions. As such, there is no control on air flow rate, inside temperature and even dust ingress. However, it is a completely green, zero energy system. A few early power plants in India used this kind of ventilation, especially in auxiliary buildings. This is no longer preferred because of its inconsistent and nature-dependent performance, coupled with the problem of dust ingress.

Exhaust Ventilation

All present day power projects employ mechanical ventilation using fans. This is achieved either through exhaust, or supply, or a combination of both. An exhaust ventilation system is designed to remove foul/ hot air, usually from a high level, unless the fumes are heavier than air, in which case the extraction would take place near the floor/occupancy level. This extraction creates an area of negative pressure, causing outdoor fresh air to flow into the room through suitably spaced low level intake grilles/openings. This is by far the most common, economical and simplest system of mechanical ventilation. This, however, provides no control on dust ingress. This works well where outdoor dust load is not significant. The room is always under negative pressure, and leakage of air is inwards in an uncontrolled manner.

Supply Ventilation

A supply ventilation system blows in fresh air (generally filtered and often pre-cooled) which mixes with the air already in the room and forces its way out to the atmosphere through any available openings. Careful location of supply fans and their even distribution are necessary to prevent heat pockets. The room is under a slight positive pressure, and leakage of air is outwards from the room. There is always an ex-filtration of air, which keeps outdoor dust away.

A combined system, often know as the push-pull system, using both exhaust and supply systems, can be more effective than exhaust-only or supply-only in large premises, as it carries out controlled mechanical intake of air directed towards specific spots, coursing air in a specific direction, and exhausting it out from a specific area. A balance can also be struck between the supply and exhaust rates to maintain the desired pressurization level in the building. Supplying filtered and often pre-cooled air is very common in the push-pull type of ventilation system.

Ventilation Systems in Power Plants

Thermal Power Plants

Coal based thermal power plants constitute the largest segment of power plants in India. About 55% of power generation in India is from coal based thermal power plants. The heart of any power plant is its Turbine-Generator (TG) building, which houses turbine and generator with their major auxiliary equipment. It often houses control rooms, switchgear rooms and cable spreader rooms also. A power plant has many auxiliary buildings, like various pump houses with their control/electrical switchgear rooms, electrostatic precipitator (ESP) control building, switchyard control building, coal/ash handling plant control building, wagon tippler/ track hopper control room, demineraliser (DM) plant building, compressor house, some laboratories, etc. All enclosures, except major control rooms and some office areas, are provided with ventilation.

All equipment enclosures including TG buildings in earlier power plants in India were provided with mechanical exhaust system with natural suction. Outdoor air used to enter naturally into the building through louvers/windows at the lower level of the external wall. Hot and stale air was exhausted outside by roof/ wall mounted axial fans. Ventilation was considered to be a money-wasting psychological support to workmen. Some engineers used to spend a part of their time designing and implementing ventilation systems, apart from their other work. The outdoor environment level has improved a lot in recent times through the use of ESP, high stack height and dust extraction/dust suppression systems in coal handling plants, compared to the earlier days when it was full of coal dust and ash. Exhaust ventilation used to bring them inside the buildings in an uncontrolled manner resulting in dusty indoor conditions. TG building, housing large heat producing equipment and extensive steam piping, was also very hot. Hot spots were very common.

This situation has changed. Ventilation has become an important engineering subject in industry. All types of ventilation systems are used in power plants. Every system is well thought out. Exhaust ventilation is used in all pump houses, most of which are generally away from dusty areas, and are often unmanned. Supply ventilation is also very useful in these cases. The supplied air, if directed at high velocity over hot motor bodies, breaks the hot boundary layer over them. This removes the virtual insulating blanket covering them and improves heat dissipation. Filtration of supply air, however, is not necessary in this case, as pump houses are not located within dusty areas.

Exhaust ventilation is also used in fume and odour producing areas like the DM Plant, chlorination plant, stores, fuel oil pump house, pantries and toilets. Exhaust ventilation in these areas creates a negative pressure in the building, allows infiltration only through the opening in the building envelop and stops uncontrolled fume and odour leakage into adjacent areas. Batteries in battery rooms produce hydrogen during charging, and these rooms are also provided with exhaust ventilation to prevent uncontrolled leakage of hydrogen to other areas. Hydrogen is diluted and exhausted out by fans. Hydrogen being lighter than air, exhaust fans are located at a high level. Exhaust fans handling explosive gases have spark proof construction, and are provided with flame proof motors. Fans used in corrosive environment, like in the chlorination plant and battery rooms, are made in split construction to keep the motor away from corrosive air, and the fans are provided with anticorrosive coating.

Compressor rooms are provided with supply ventilation with fan filter units. The air quantity required for ventilation is increased by the amount the compressors will suck in. Small control rooms of pump houses and other auxiliary buildings generally use pressurised supply ventilation using fan filter units.

TG buildings are manned, and are also packed with large heat producing equipment and steam piping. They have elaborate ventilation systems which are expensive and power consuming, and therefore need careful design and implementation. Ventilation systems in TG buildings have undergone extensive changes. They started with just some roof exhaust fans and air intake through building openings, windows and louvers. In the early days there was no physical partition between TG hall and the adjacent mill area, filling the entire area with coal dust. The inside environment was totally unacceptable for men and machines. Later the mill area was isolated from the TG Hall by partition walls. Air was supplied by fan filter units and exhausted through roof extractors, being distributed inside through ductwork. There was some pressurisation in the building to improve the cleanliness of TG halls. Auto-viscous type filters were used (see *Figure 2*) to reduce the need for frequent cleaning. Still there was no respite from high temperatures.

Figure 2: Auto viscous filter

Air washers

Evaporative cooling was introduced in the late nineteen-seventies by using double bank spray type air washers to offset the large heat load. Larger quantity of air is supplied to the ground and mezzanine floors. After picking up heat from the lower floors, air moves up to the operating floor. It combines with some more air supplied there, picks up heat and moves out through TG hall roof extractors. The TG building has many large openings for material transport. Exhaust is generally kept at around 60 – 70% of the supply air to maintain positive pressurise and keep the dust away. Washed air is also supplied to the switchgear and cable spreader rooms in the TG building. Supply air is returned to the TG hall through some back draft dampers for further use.

With the difference in ambient dry and wet bulb temperature (often known as wet bulb depression) and about 90% saturation efficiency of air washers, the temperature in the TG hall is often maintained close to, or at times even lower than, the ambient temperature. Humidity is controlled by on/off control of air washer pumps though a space humidistat.

Some initial air washers used axial flow fans due to ease of layout. But because of their high noise levels, they were replaced by centrifugal fans.

Early air washers were all masonry type (see *Figure 3*), and were not installed on upper floors. All air washers were located on the ground floor on one side of the TG building. No air washer was located on the mill side or high up in the electrical/deaerator bays.

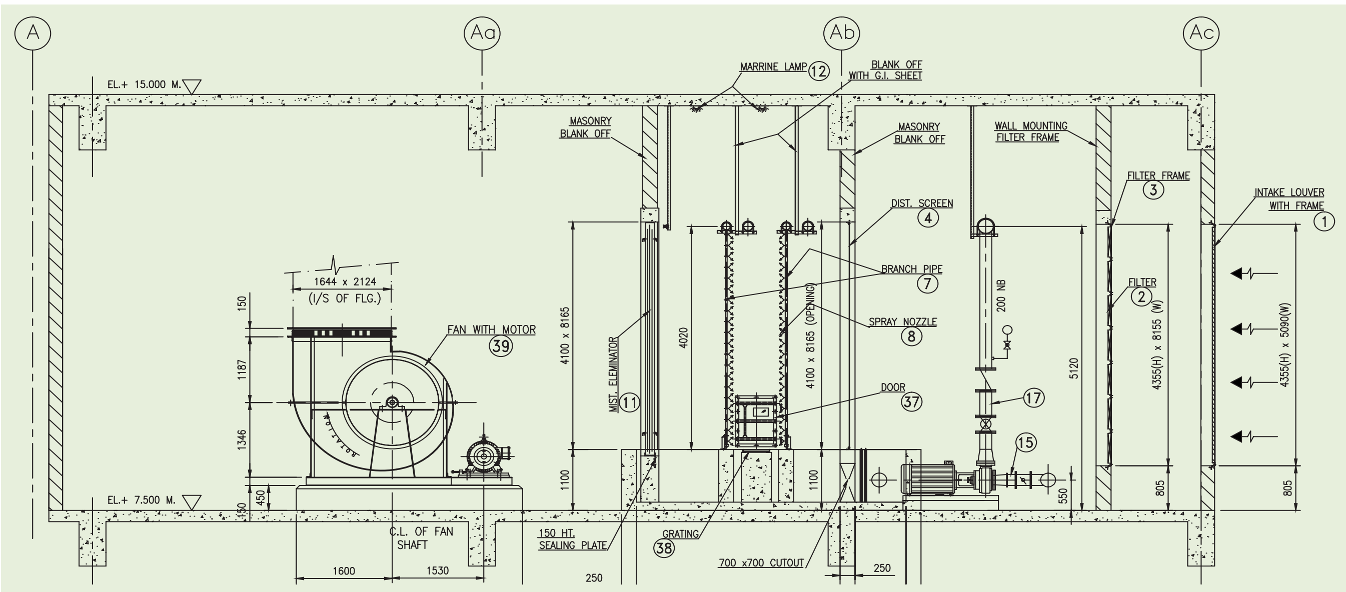

Figure 3: Masonry air washer

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Duct crossover across the TG bay was a challenge. At times, large buried RCC underground ducting was used to carry washed air to the electrical bays.

Sheet metal air washers (see *Figure 4*) were introduced in the early nineteen-eighties. Multiple units of air washers are now used on either side of the TG unit to avoid duct crossing in TG bay.

The performance of auto-viscous filters proved unsatisfactory. Coal dust/ash with filter oil formed a sticky sludge coating the filter wire mat. It was difficult to clean the mat in such a condition. The air flow kept reducing over time and finally auto-viscous filters gave way to dry, cleanable, HDPE panel filters. They are still in use. But many users want to minimise, or possibly do away with, filter cleaning. This brought in washable stainless steel metallic wire mesh filters with water spray over them.

Nozzle material is variable across the industry. Air washers use polypropylene (at times SS tipped), brass, bronze (at times chrome plated) and stainless steel nozzles. Polypropylene is the cheapest, but there are incidents of their bursting at high operating water pressure. Brass and bronze get stolen. Stainless steel is expensive. Considering the large number (about 1500 for a 3,00,000 CMH air washer) of nozzles required for high capacity air washers, there is substantial cost variation with the type of nozzle material.

Moisture/droplet eliminators for earlier air washers were made of GI/aluminium. Since they are costly and lack dimensional stability/uniformity, they are slowly being replaced by PVC eliminators. PVC moisture eliminators (see *Figure 5*) are made with around 2 mm thick virgin PVC, and are provided with droplet arresters.

With upscaling of power plants, the sizes of air washers are also increasing. Earlier air washers were restricted to between 1,00,000 and 1,30,000 CMH capacity. These were often used with Single Inlet Single Width (SISW) centrifugal fans. Double Inlet Double Width (DIDW) fans were used only in masonry units. Nowadays 3,00,000, or even 5,00,000 CMH air washers are common, and they are built in sheet metal construction for use in upper floors in the electrical bay. These large air washers need DIDW fans, often in multiple numbers. This calls for the spray chamber with water tank to be constructed in sheet metal, and to be housed along with the fans in a masonry room. There is a trend towards replacing the masonry room by enclosing the fans in a sheet metal casing. Pumps are sometimes housed within this sheet metal enclosure. This adds a large amount of steel and cost to air washers. The need to take the turbine rotor out of the TG hall through the transformer area for maintenance/ repair work in some ultra mega power projects demands sheet metal construction of air washers even on the ground floor. This allows quick dismantling and removal of air washers. They can be assembled back once the turbine rotor is replaced. It is necessary to assess the frequency of such maintenance/repair requirements and explore alternative locations of air washers before going for such expensive construction. Transportation of various large components and panels of such air washers is also a challenge.

Figure 4: Sheet metal air washer

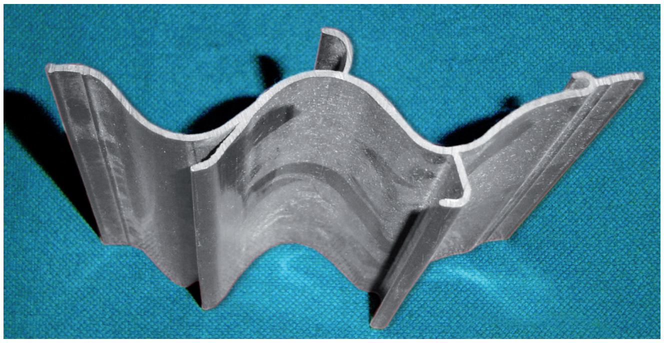

Figure 5: PVC moisture eliminator

Non-control room electrical areas of ESP control buildings and, at times, switchyard control buildings also use evaporative cooling with single bank spray type Unitary Air Filtration (UAF) units with about 60% saturation efficiency. In spite of this low saturation efficiency, the air quantity can be kept at a low level in view of lower heat load in these buildings.

Hydel, Combined Cycle and Nuclear Power Plants

India had a few small hydro power stations before Independence. The first of them, Bharachukki in Mysore, was built in 1902, followed by Mohra in J&K which came up in 1905. Now we have many of them, and their sizes are increasing. Combined cycle and nuclear power plants are later technological developments.

In the recent past there has been an emphasis on hydro power plants. They are generally located in cool and clean climatic areas, and there is no coal or ash in the system. Fan-filter units supply air to the power house building. Because of generally mild ambient conditions, a part of the air is re-circulated, with about 25% fresh make up air. The foul return air from battery rooms and toilets is collected in a separate exhaust duct, re-used to ventilate the cable tunnels, and then discharged into the atmosphere. Fresh air units are fitted with pre-filters, and the recirculation units are sometimes fitted with fine filters also. Locating ventilation equipment suitably is often a challenge because of the hilly terrain in most locations.

Gas turbine based combined cycle power plants, like hydro power plants, do not have any coal or ash in the system. But they are generally located in high ambient areas, and their power

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house building or ST/GT (Steam Turbine/Gas Turbine) building uses ventilation with evaporative cooling, with supply and exhaust through roof extractors.

Nuclear power plants have two separate islands – the nuclear island and the power island. The nuclear island includes a nuclear steam generating system and other facilities using radioactive material. Special care needs to be taken while designing ventilation systems in this area. Each area in this island is designed with relative pressure gradient to stop the flow of radiation in any situation. Air is exhausted from Reactor Containment Building (RCB) through pre-filters and HEPA filters.

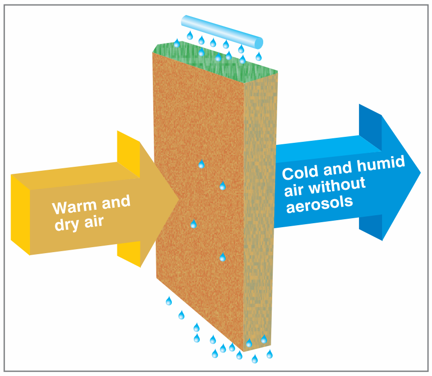

Figure 6: Cooling pad


Figure 7: Wind fans

The power island houses the turbine building with electrical annexés and the balance of plant including all pump houses, DM plant, switchyard building etc. Ventilation of the power island is similar to that in a thermal power plant.

(Please see feature article "Air Conditioning and Ventilation for a Prototype Fast Breeder Reactor", Air Conditioning and Refrigeration Journal, Oct.-Dec. 2011, pages 98-108 – Technical Editor.)

Cost Saving and Future Trends

The approximate power consumption for ventilation systems in modern large power plants is about 0.12% of the installed capacity, i.e. about 1200 watts per megawatt of generation. This amounts to 4800 kW for a 4000 MW ultra mega power plant. About 50% of this is consumed in the TG building. This indicates the scope for power saving in the ventilation system of power plants, more so in its TG building. *Table 1* gives an analysis of various systems currently being used/considered for ventilation of TG buildings.

The pump size reduces for air washers with cooling pads (see *Figure 6*). There is a saving of about 398 kW on account of pump power. This also reduces water requirement for air washers.

As a power saving measure, replacement of electrically driven roof extractors by wind fans (see *Figure 7*) is also being explored wherever possible. This may also save a further 238 KW for the kind of large power plant described in *Table 1*.

Wind fans work on a combined motive force of stack effect and ambient wind speed. Stack effect is determined by the temperature difference between exhaust and inlet air. Wind fans generally produce acceptable air flow when this temperature difference is about 10°C and the wind speed is around 10 – 12 kM/hr. However, most Indian stations have an average wind speed between 5 and 10 km/hr, and a 10°C temperature difference in Indian summer conditions is not very common.

Windmill designers also look for energy friendliness of wind in a particular station. This is approximately equal to the ratio of cube of mean air speed and square of extreme air speed multiplied by a factor (approximately 1000). Extreme-to-mean ratio is also important; it is within good limits in 50% of the US land area, whereas it is in the recommended range only in 15% of the Indian land area. This makes wind fans less suitable in most stations in India. Careful study is, therefore, necessary before deciding on the use of wind fans in any location.

Hybrid wind fans have been developed to combat the uncertainty in ambient wind speed. These fans run on electricity when the ambient wind speed falls.

Table 1: Ventilation of TG Building in 4000 MW Ultra Mega Power Project

Ambient conditions (summer) : 42.4°C DB, 27.5°C WB
Air washer saturation efficiency : 90%
Equipment load : 4500 kW

	Spray type air washer	Cooling pad type air washer	Fan filter unit	Air conditioning
Inside temperature, °C	40	40	47.5	35
Approximate plant capacity	50,00,000 CMH	50,00,000 CMH	1,34,10,000 CMH	2200 TR
Approximate fan pressure, mm of WG	75	75	35	-
Air washer fan / AC plant power, kW	1418	1418	1774	4400
Pump power, kW	817	419	0	-
Roof extractor power, kW	238	238	639	-
Total Power, kW	2474	2007	2413	4400
Equipment cost, Rs. (crores)	17.5	20	21.5	17.6

Some basic engineering practices may save power further. Use of energy efficient motors has become a common practice in upcoming power projects. These motors have about 2 – 3% higher efficiency, and they cost just about 7 – 10% more. The payback period is hardly 6 months for general ventilation fan motors.

Centrifugal fans in ducted ventilation systems (including those in air washers) generally do not operate at specified duty points in spite of all the design efforts. Large safety margins are generally used, and in most cases the operating point is achieved by damper control at fan outlet.

This unnecessarily forces the fan to operate at a high pressure. Variable inlet vanes can improve the situation. But, in moist air conditions prevalent in air washer, they have a short life span.

As most of these fans operate at fixed duty points throughout their life spans, the option of adjusting their speed by changing the fan/motor pulley during the commissioning/air balancing stage may be seriously considered. If the fans can be set to operate at a pressure just 3 mm WG lower than the specified 70 mm, operating these fans without volume control by damper can save up to 5 – 6% energy. Variable frequency drives (VFDs) may cost about 100% higher than conventional starters, but their payback period is just 8 – 10 months. Using VFDs with room temperature sensors will allow the fans to run at lower speed in milder seasons. This will further improve power consumption.

Conclusion

The Indian government has set ambitious goals for the power sector owing to which it is poised for significant expansion. In order to provide 1000 units per capita availability, there is a need for massive capacity addition plans for generation, transmission and distribution. Ventilation requirements in the power sector will grow proportionately. With wide variations in ventilation systems used currently, it is now time to critically review the applicability of each system in each area. Uniformity in ventilation systems with a strong emphasis on power saving is the need of the hour. ❖