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Sustainable Architecture for Power System Planning & Scheduling

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Abstract—*Carbon-di-oxide emissions has bring a new challenge nowadays due to regulation from electric power industry to mitigate global warming.*
Focusing on the facts & figures of Central Electricity Authority (India), we need are providing the optimal strategies for planning to address the challenging issues and enhance the efficiency and sustainability of power system. Our paper proposes integration of new optimized techniques of significant level for betterment of existing systems along with adoption of advance & renewable energy systems into the electricity grid in effect to Executive Summary for the Month of Sept, 2016 of India.

1. INTRODUCTION

In a centralized electric power system, an appropriate planning & generation scheduling is derived by the system operator and imposed to producers. The target in assembling such a plan is to achieve an appropriate blend between maximum efficiency and minimum cost. Note that maintenance outages decrease reliability and increase operation cost. However, this centralized framework is not anymore valid in currently restructured electric energy systems in India.

India has the fifth largest electricity generation sector in the world at 306558.35 MW in 2016(CEA, 2016). Of the total electricity generated, thermal power plants (coal & gas) account for 61% & 8%, hydroelectricity for l5%, renewable energy sources for and the remaining 10% from other sources including natural gas and nuclear energy & diesel.

In 2015-16, we estimated that the 111 coal-fired power plants consumed 545.8 million tonnes of coal in total – emitting around 600 kilotonnes particulates with diameter less than 2.5 micrometers (PM2.5), 2,100 kilotonnes of sulphur dioxides (SO2), 2,000 kilotonnes of nitrogen oxides (NOx), 1,100 kilotonnes of carbon monoxide (CO), 100 kilotonnes of volatile organic compounds (VOCs) and 665 million tonnes of carbon dioxide (CO2). (Statistics Related to Climate Change – India 2015)

These emissions resulted in an estimated 80,000 to 1, 15,000 premature deaths and more than 20 million asthma cases from exposure to total PM 2.5 pollution, which cost the public and the government an estimated Rs.16000 to Rs.23000 crores. The health impacts analysis of these emissions was carried out via state-of the- art dispersion modelling system (CAMx) and the use of health risk coefficients established by epidemiological studies. We believe that the health impacts discussed here is an underestimation, and does not include the impacts of the water run-off and soil contamination due to the release of heavy metals like zinc, copper, manganese, cobalt, cadmium, selenium, mercury, arsenic, iron, lead, and chromium. The particulate matter (PM) pollution from coal-fi red power plants in central India covering Madhya Pradesh, Jharkhand, Odisha, and Chhattisgarh, is the highest due to the density of the power plants in the region and higher installed generation capacity because of its proximity to coal mines.

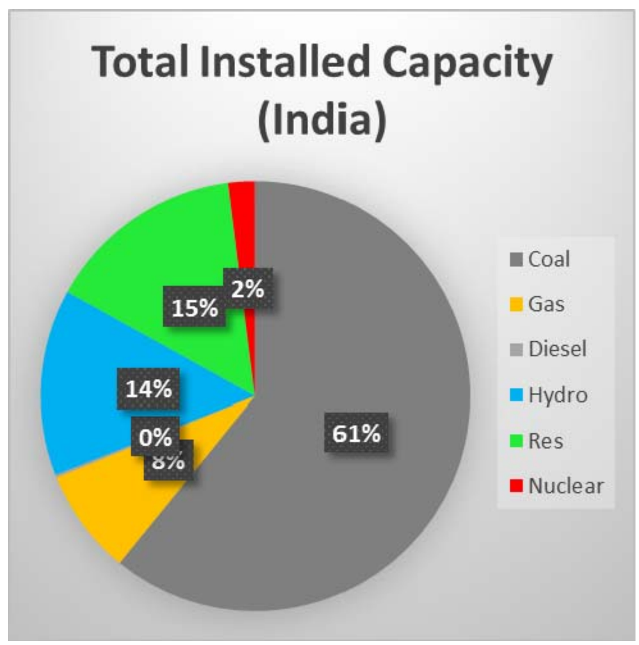

Fig. 1: Current Power Generation – India
(306558.25 MW)

The Delhi-Haryana region with the highest population density, with more than 21.5 million inhabitants in Delhi and its satellite cities, also experiences substantial PM pollution from coal-fired power plants. According to the World Health Organization, 25-30 cities in the top 100 most polluted cities in the world are from India.

Fuel prices have become a huge factor of determination for India. Gas prices increase has an influence on oil price increase. According to a shift in terms of trade, a huge price rise results in transfer of income from oil importing to oil exporting countries.

As an effect of this, the oil exporting countries profits their nation by a huge amount by these export earnings. Also the rise in fuel prices have negative impact on oil importing countries while these countries must produce goods and services in place of huge export of oil from these countries.

2. AGGREGATE TECHNICAL & COMMERCIAL LOSSES

"AT&C Losses is the sum total of technical loss, commercial losses and shortage due to non-realization of total billed amount"

A. *Formula*:

{(Total Energy Input LESS Energy Realized)/ Total Energy Input}*100

Table 1: AT&C Losses (%) – India

Time Span	2010-11	2011-12	2012-13	2013-14	2014-15
AT&C Losses (%)	26.35	26.63	25.48	22.58	24.62

India is having around 25.62% of loss from the total installed capacity. In the current scenario, it is practically not possible to eliminate all the causes simultaneously in our country. It is found that there are various factors responsible for AT & C losses which need to be eliminated. The following measures should be taken to marginalize the major causes of losses.

B. Technical losses

Technical loss of a network is a result of network design, specification of the equipment used in the network and the network operation parameters. They can be cured by:

I. Adopting high voltage distribution system with regular maintenance of distribution network to prevent overloading of system elements like transformers, feeders, conductors.

II. Inclusion of capacitor banks, i.e. sufficient reactive compensation.

III. Reconfiguration of feeder lines and distribution transformers.

IV. By usage of smaller size energy efficient Distribution transformers & AVB (Automatic Voltage Booster)

V. Laying Additional link lines along with using advanced methods for preventing leakages at insulators (like using nano-pore powders).

C. *Commercial losses*:

The causes for commercial losses are theft and pilferage, low metering efficiency, faulty meter reading, inefficient billing, under-billing, faulty bill distribution, software errors, prolonged disputes or inadequate revenue collection. These can be cured up to very high extent by:

I. Defining installation procedures and ensuring that installation check points are tested/followed while installing meters.

II. Use of electronic meters with tamper and load survey logging features for all categories of consumers.

II. Use of optical port for taking the reading for all categories of consumers.

IV. Seating of meters with seals and having proper seal management system.

V. Installation of CTs/PTs in sealed boxes so that terminals are not exposed for tampering/bypassing.

VI. Testing of the metering system as a whole to ensure accuracy along with ensuring accuracy in meter reading and billing activities by generating exception lists.

VII. Carrying out regular energy audits covering all end consumers to ensure that there is no revenue leakage beyond the permissible technical loss.

We can reduce the AT&C losses to some extent but We cannot eliminate them completely we can reduce them to below 10% so that the gap between the generation and utilization will be reduced hence government sector will be ahead in the competition with the private sectors which in turn helps to improve our Indian economy.

3. TRANSMISSION AND DISTRIBUTION (T & D) LOSSES

In India, the true fact is that whole of the energy does not reach the end consumers which is supplied by distribution utility. By way of technical losses, a substantial amount of energy is lost in the distribution system. These inherent losses in transmission and distribution of electrical energy from the generating stations to the ultimate consumers should be reduced by eliminating or minimizing the causes of losses. T & D loss is the difference between units injected into the system and the units billed to the ultimate consumers, which is generally expressed as percentage of units injected. It is generally calculated for a period of one financial year: Hence,

T & D losses (%) = [(Energy input – Energy bill) X 100]/ Energy input {for one financial year}

Table 2: T&D Losses in India

Time Span	2010-11	2011-12	2012-13	2013-14	2014-15
T&D Losses (%)	23.97	23.65	23.02	21.46	22.77

For the immediate, feasible and effective improvement of losses in technical system based on details collected from existing system and statistical scrutiny are:

I. *Network Reconfiguration* – For handling the day by day increasing demand and system reliability, it is the best option. It is effective when voltage drops between the nodes to be linked is rich and the distance between the nodes is short. Within a feeder it is effective only when the zigzag factor is high.

II. *Network Re-Installing* – As per the basics of electricity, current density and resistance of the line are determined by the size of the conductor. In India, a regular practice is found for reducing revenue. Due to unavailability of stock & government problems, conductors that cannot deliver peak demand of the consumers at the correct voltages are installed at some places. Revenue is reduced as a lower size conductor size can cause high I^2R losses and huge voltage drop. Recommended practice of finding out whether conductor is able to deliver peak load at correct voltages must remain within the limits set in Indian Electricity Act, 2003.

III. *Preventing Leakages at Insulators* – Insulators plays an important role in transmission of power. Insulators fail either by flashover of charge or by puncturing. A lot of money is wasted in insulator failure every year in India. Use of good materials like high quality porcelain or glass and having good arrangement for dust & pollution is a good preventive actions. Regular inspection & hot line washing must also be a regular practice.

IV. *Automatic Voltage booster* – Around 10% of the total voltage is reduced by these new technology devices. These devices has working similar to the series capacitor, in which when pointer points in discrete steps whenever the tap changer boosts the voltage. This reduces the loss in the forward location and also improves voltage profile by a great extent. It boosts the total voltage by 10% in around 4 steps.

V. *Better Management of Distribution Transformers* – The distribution transformers provides final voltage transformation and to be taken care very sensitively.

In this regard the measures by management like addition & augmentation, reallocation of distribution transformers at load centers must be done. Also switching to more efficient available transformers and proper guarding in oversized, undersized, low loading transformers must be a regular practice. Proper guarding should also be done against hot spots in core, low oil/level leakages, bushing connectors etc.

4. GENERATION ADVANCEMENTS

The following are the proposed technologies which can be added up in the existing generation system for improvisation.

A. Fluidized Bed Combustion Boiler Technology

Most of the coal in India is of low quality, very high ash content & huge calorific value. Traditional Indian boilers users have got a lot of techno-economical limitations & challenges (in their fuel firing systems) to meet in future with the coal consumption of 545.9 MT, which the highest yearly amount till date.

New Fluidizes combustion boilers with advantages like reduced emission of noxious pollutants such as SOx and NOx, smaller boiler design, higher efficiency of combustion and flexibility of fuel are a viable and significantly better over conventional firing system.

With a wide capacity range from 0.5 T/hr to 100 T/hr, FBC boilers can burn washery rejects, rice husk, bagasse, agricultural waste along with the coal.

The other advantages of FBC boilers over traditional boilers are:

I. Efficiency: Irrespective of the ash content, these boilers can burn fuel with a combustion efficiency of around 95% which is very high than the existing ones.

II. Reduction in Size of Boiler: Due to very high heat transfer rate in small area, these boilers size is reduced which not only reduces the cost but also auxiliary power consumption.

III. Flexibility of Fuel: This is the biggest merit of these boilers, they can burn variety of fuels like agro waste, bagasse, husk, floatation slimes, washers rejects very efficiently. Also these FBC's can burn coal with high ash contents (around 62%) and calorific value as low as 2500kCal/kg.

IV. Ability to Burn Fines

With the existing conventional firing system it is not possible to burn fines of smaller size but by FBC technology we can burn fines below 6mm which contributes in increase of the efficiency.

V. Pollution Control

Firstly, due to low temperature combustion in FBC eliminates NOx formation. Also the SO_2 is easily minimized in this combustion technology by addition of limestone or dolomite (for high sulphur coals). Around 3% of limestone is required for each percentage of coal burned. Inside the boiler.

VI. Easy Ash handling System
Easier Ash Removal – No Clinker Formation

Clinker formation in any boiler occurs when the temperature of furnace goes above 1100 °C. Due to temperature of around 750-900 °C in FBC boilers, no clinker formation take place.

Also without clickers the coal with low ash fusion temperature can be burnt easily in FBC boilers. So, ash removal is easy and requires less manpower in ash handling plant maintaining the economy.

B. Retrofitting of Boilers

Retrofitting of conventional boilers not only helps in tapping the waste heat but also helps in recovery of great amount heat lost to the environment by flue gas. When deciding whether to replace or retrofit a boiler, the boiler's overall condition, not its age, should be the determining factor. Before setting up retrofits, i.e additional equipment into existing needs technical as well as theoretical justification.

The few advantages of retrofitting of boilers are:

I. It is a short investment process as the cost intensive components already available within the plan.
II. The overall life of the power plant increases by addition of few equipment.
III. Feasible use of liquid and gaseous fired applications along with easy integration.
IV. Problems like high-temperature corrosion and other ash fusion issues are easily resolved in retrofitting.

C. Shale Gas

The shale is the result from compaction of mud & mineral contained small old sedimentary rocks-like quartz & calcite, trapped beneath earth surface. Within these shale rocks natural gas shale is trapped. Along with the coal bed methane, methane hydrates and tight sandstones, shale is also an unconventional type of gas.

India's first successful shale gas drilling was explored in Cambay region, i.e Jambusar near Vadodara in Gujrat.

Shale gas is definitely an opportunity and if explored and exploited effectively, it could fulfill the major energy requirement of the country. The unlocking of domestic shale gas can help India meet its growing energy demand, besides reducing its dependence on expensive energy imports and the energy import bill. The shale gas resources in India were untapped due to lack of technological knowledge, expensive tools and technology, socio-political conditions of the country, lack of R&D facilities and its funding etc. However, with the advent of new technologies and the growing energy needs coupled with appropriate market prices and policies make this time right to explore & exploit this resource on equal priority.

5. SMART GRID

Smart grid is basically a two way communication electrical network which supplies power to consumer by using digital technology. Continuous monitoring, analysis, control & communication within the whole network gives greater efficiency and good supply chain management system.

Smart grid concepts encompass a wide range of technologies and applications. A few below the table are currently in practice with the caveat that is existing, at this early stage in the development of smart grids.

Table III: Comparison between the Existing Grid & the Smart Grid

EXISTING GRID	SMART GRID
Electromechanical	Digital
One way communication	Two-way communication
Centralized Generation	Distributed Generation
Few Sensors	Sensors throughout
Manual Monitoring	Self-Monitoring
Manual Restoration	Self-Healing
Failures & Blackouts	Adaptive & Islanding
Limited Control	Pervasive Control

i. AMI-Advanced metering infrastructure. Firstly, by using real-time metering information automatic meter reading (AMR) systems provides an initial step toward lowering the costs of data gathering. Secondly, in AMI a single point of integration is set for the full range of meter by use of meter data management (MDM). This improves the system accuracy and also supports the factors of decision making. By enabling leverage of the data to automated business processes in real time and operational applications, efficiency improvement and decision making across the enterprise becomes easy.

ii. GIS-Geographic information system technology is nowadays being designed for the utility industry for good and real time management of the site along with their critical infrastructure. By merging utility data and geographical maps in the grid, GIS will provide a satellite view of the whole grid which will not only called ad as new monitoring but will also reduce cost through the simplified planning.

iii. DMS-Distribution management system software. By this mathematical models of the electric distribution network are made and prediction of the factors of outages, transmission, generation, voltage/frequency variation, and more are done. It helps by reducing capital investment by showing how to have a good modelling and better utilization of existing assets. Also by giving a fair idea of enabling peak saving via demand response, it improves network reliability too.

iv. Outage management systems (OMSs). It speeds up the outage resolution so power should be restored more rapidly and outage costs are contained fairly for the whole system.

v. Intelligent electronics devices (IEDs) are advanced, application-enabled devices installed in the field that process, compute, and transmit pertinent information to a higher level. IEDs can collect data from both the network and consumers' facilities (behind the meter) and allow network reconfiguration either locally or on command from the control center.

vi. Wide-area measurement systems (WAMS) provide accurate, synchronized measurements from across large-scale power grids. WAMS consist of phasor measurement units (PMUs) which shows time-stamped data in graphical form, together with phasor data which aggregate the data and perform event recording simultaneously.

vii. Energy management systems (EMSs) at customer premises can control consumption, onsite generation and storage, and potentially electric vehicle charging. EMSs are in use today in large industrial and commercial facilities and will likely be broadly adopted with the rollout of smart grids.

6. RENEWABLE ENERGY AND RESEARCH & DEVELOPMENT

Renewables contribute about 15% of the total installed capacity in the country (CEA, 2016). Around 97% of the installed capacity is grid-connected and off-grid power constitutes a small share (MNRE, 2015).

Because of the imbalance of nature and Inequality in energy distribution, renewable energy has the maximum probability of becoming the foundation for the country's future energy. Wind is the mainstay of grid connected renewable power in India.

Renewable energy is an important agenda of India's power planning process especially since climate change has taken a big role in both domestic and international policy arena.

The Government of India has projected capacity addition of 72,400 MW by end of the Thirteenth Plan (2022), of which solar is expected to contribute 28%. . Also dynamically vibrant systems are required to support recent advancement in the technologies, especially in solar. The wind industry in India is globally mature, occupying the sixth position in wind turbine manufacturing, the solar industry is still growing and ramping up its manufacturing capabilities. Also the R&D activeness in innovations and other power generation fields must be improved, like *Renewable heat* where solar is concentrated to feed radiators and using it as preheaters in power plants. Also the recent invention *Pervoskite.* The performance of metal halide perovskite solar cells has made rapid increases in energy conversion efficiency, improving from under 4% efficiency in 2010 to a record efficiency of 22% in 2016.

7. CONCLUSION

Our paper addresses the notions of conveyance and reliability of the grid and their qualitative impacts on power system efficiency. Considering the facts of possible improvisation in present techniques our paper is proposing advancements of generation, transmission and distribution in the existing system along with switching to new technologies. Furthermore, a new dimension will be introduced into generation planning by penetration of intermittent highly efficient renewable energy sources which will be ensuring decrease in dependency on fossil fuels in future, leading to operational flexibility and a good balance of generation. Also having advanced and highly efficient systems will allow us to assess network reliability and a suitable dynamic dissipative processes over the electrical network.

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