Tejal Kanitkar
Nikhil Thejesh
Upasna Ranjan
R. Srikanth

Optimal Electricity Mix for the Southern Region

Summary Report of NIAS – MOES Workshop, 17th January 2020

National Institute of Advanced Studies
Bengaluru, India

Workshop Report NIAS/NSE/EEP/U/WR/07/2020

Optimal Electricity Mix for the Southern Region

Summary Report of NIAS – MOES Workshop
17th January 2020

Energy and Environment Programme
National Institute of Advanced Studies
Bengaluru, India
2020

Published by
National Institute of Advanced Studies
Indian Institute of Science Campus
Bengaluru - 560 012
Tel: 2218 5000, Fax: 2218 5028
E-mail: publications@nias.res.in

NIAS Report: NIAS/NSE/EEP/U/WR/07/2020

Cover photo: Front cover
World's largest solar park (2050 mw) at Pavagada in Karnataka is now fully operational

Back cover
India's first Ultra-Supercritical (USC) power plant commissioned in Khargone, Madhya Pradesh with an efficiency of 41.5% and station heat rate of 2050 local/kWh. (Courtesy: NTPC)

Typeset & Printed by
Aditi Enterprises
aditiprints@gmail.com

Contents

Background

The theme of the one-day workshop at the National Institute of Advanced Studies (NIAS) was "Optimal Electricity Mix for the Southern Region". The aim of the workshop was to present the results of studies undertaken by the Energy and Environment Program at NIAS and to get feedback and other overall inputs from experts and practitioners in the power sector regarding the theme. The presentations in the workshop included the current overall situation of the power sector, the challenges in renewable energy integration, and ongoing interventions and modeling efforts to better manage a diverse and large Indian power system, with a specific focus on the southern region in India. The overall aim was to arrive at a set of suggestions as well as research directions to address the question of economic burdens on increasingly stressed distribution companies in the country as well as to make the best use of available resources in an environmentally sustainable manner.

The workshop had four sessions- an Inaugural session followed by two technical sessions and a round table discussion as the concluding session. The range of topics covered were generation expansion planning for India, evaluating the financial implications of emissions reductions in the southern region, optimal thermal energy use to compliment increased infirm power supply in the grid, regulatory and infrastructural challenges to renewable energy integration, developments in clean coal technology with a focus on coal gasification, and strategies for ensuring overall environmental sustainability in the coal and lignite fired power plants.

Session I: Inaugural

Prof. Shailesh Nayak, the director of NIAS formally inaugurated the session and highlighted the need for dynamic models in power system and environmental studies. In a situation of rapidly changing atmospheric and physical systems, as well as changing global and national targets, the need for dynamism in models is crucial. Given the political mandate of achieving the Sustainable Development Goals (SDGs), the Director also emphasized the importance of models to be able to quantitatively analyze the routes to meeting these targets.

Prof. Srikanth, Dean of the School of Natural Sciences and Engineering and also Head of the Energy Environment Programme (EEP) at NIAS introduced the background of the workshop. He underlined that one of the primary goals of the workshop was to share the interim results of ongoing work at NIAS with the experts and practitioners in the field in order to get continuous feedback. He also acknowledged the support extended by the Southern Region Load Dispatch Centre (SRLDC) of POSOCO which has been an important partner for NIAS in pursuing our research on the optimal electricity mix. He also stated that while NTPC, TSGENCO and KPCL had participated in the NIAS workshops, other State utilities in the Southern region had also participated in discussions held in their offices.

Prof. Srikanth stressed the significance of the Southern Region in India's power sector since it houses 49% of the total renewable energy generation capacity in the country. However, he clarified that the eventual aim of NIAS is to replicate the analysis for other regions of the country as well.

Mr. S.K. Soonee, Advisor at the Power System Operation Corporation Limited (POSOCO), gave the keynote address at the workshop. He questioned the lack of merit in the "merit order dispatch" ostensibly employed by the load dispatch centers both state and regional. He pointed out that the variable costs of interstate power plants range from Re.1 to Rs.4.5 per unit. The challenge for the system is to minimize the total cost, i.e. the cheapest plants should run at the highest plant load factors. However, there are barriers to achieving this because of some long-term contracts, settlements etc. There are a total of 156 thermal power generation units, 36 States/Union Territories making purchases and on an average 0.5 million contracts to be settled on a daily basis. He pointed out the fact that relatively new units are operating at as low as 20% plant load factors (PLF) even though at the start, they were assumed to run at 80% PLF and that equal importance should be given to studies on both peak and off-peak periods of daily load curves. Current studies mostly focus on meeting peak demands only.

In order to assess the optimal mix of capacity addition for the years 2017-22 and 2022-27, generation expansion planning studies using the EGEAS/ORDENA software has been carried out by the Central Electricity Authority (CEA). One of the results from this study is that there is likely to be 4% curtailment of solar in the near

future and Mr. Soonee stressed that the generation planning exercises as policy should take this into account given the already high cost of power in the country. However, he also pointed to the need for more scientific demand forecasts.

On the transmission side, Mr. Soonee highlighted the fact that the synchronous balancing of the entire Indian power network is now complete, and the frequency variation has been considerably reduced (ranges in between 49.95 to 50.05 Hz). The current system in place however provides passive balancing which is acceptable as long as most of the balancing is due to variation in demand. However, with the new RE targets and increasing amounts of infirm capacity being added to the grid, active balancing, i.e. the use of reserves and auxiliary services, has increased. This is illustrated in Figure 1. However, higher reserves will be expensive, so innovative solutions must be developed on how existing plants can be used to provide reserve power for balancing.

In terms of generation, Mr. Soonee underlined that there is a need to increase flexibility in the system. We need to have a matrix which includes measurement, pricing, incentives and ramping requirements. The ramping requirement for thermal plants has been reduced from a 3% to a 1% rate of reduction per minute with respect to the installed capacity of a unit, However, many plants cannot even meet a rate of 0.5%. The challenge of achieving flexibility in the power supply system in India is significant. During evening peak hours, the ramping required is almost 500 MW/minute. While some short-term flexibility has been introduced in the system by reducing the scheduling times from one hourly to 15-minute basis, with increased renewable energy in the system, shorter time periods for scheduling will have to be achieved.

Mr. Soonee also emphasized that the inter-regional links and the synchronization of the national grid, now allow for inter-regional sales and exchange. The diversity in supply thus available, allows risks to be balanced across the network. There can be room for optimization and fragmented allocations. He recommended a direction to create a system wherein the guiding principle would be that the system has the ability to self-heal, and decision making would be continuous without manual intervention.

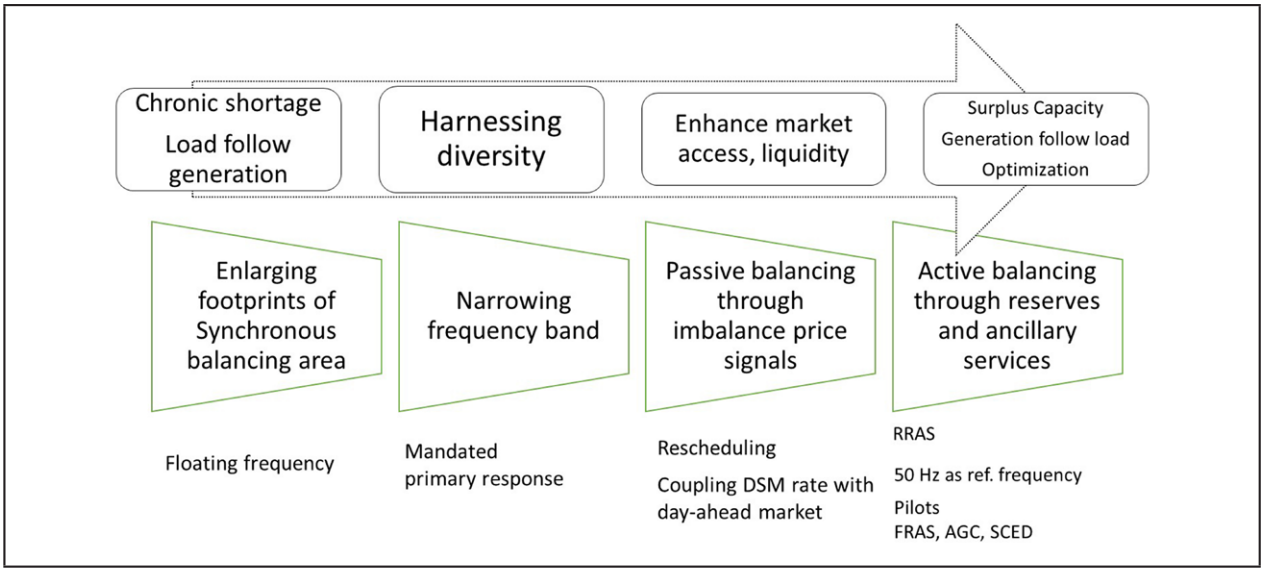


Figure 1. Existing Passive Balancing and the Need for Active Balancing in the Indian Grid

Mr. Soonee also presented a unique solution titled "Security Constrained Economic Dispatch" in the Indian Power System implemented by POSOCO as a pilot, which optimizes the allocation of the un-requisitioned surplus from the central generating stations to different states across the country (illustrated in Figure 2).

While the total amount of energy being optimally utilized is relatively less, even then it has been observed in the study there was a 43% reduction in fluctuation and an increase in plant efficiency during the time period when the SCED scheme was implemented. Mr. Soonee concluded by highlighting the fact that the grid code is now two decades old and significant changes are necessary to account for the increase in renewable energy being added to the system.

The talk by Mr. Soonee was followed by a lively round of discussion where Mr. Soonee discussed the unique features of the Indian power grid as well as the challenges before us in undertaking a transition of the magnitude that is currently planned. He commented upon the improvement in grid management in the last decade as well as the transparency that has been introduced in the estimation and publication of losses. Research on creating a multi-part tariff system may also be required when we think about the future of regulation in the power sector.

An important aspect of the power sector is that it is on the concurrent list. There has always therefore, been tension, between the states and the central government about the way in which policy directives are to be implemented and the way in which state sovereignty is affected. Mr. Soonee pointed out however that resources for energy supply as well as major load centres in the country are widely distributed spatially. If these resources have to be utilised most efficiently then states will have to cooperate and work in unison and it is the job of the regulator to ensure the same.

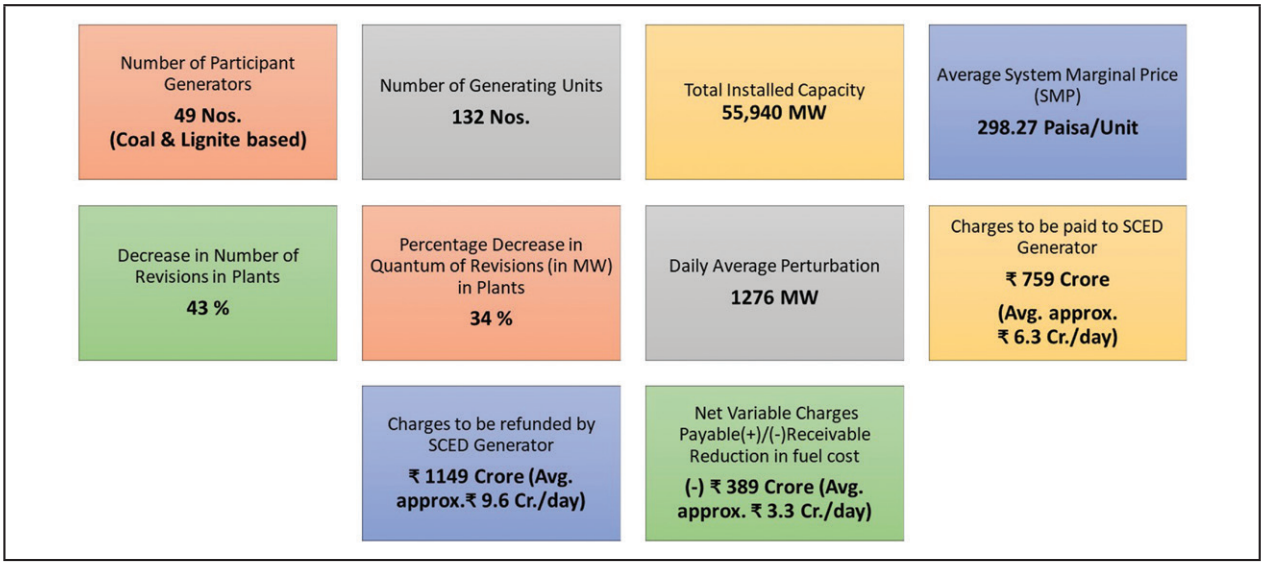


Figure 2. Overview of the Pilot SCED implemented by POSOCO

Session II: Challenges for Renewable Energy Integration: Focus on Southern Region

The second session was chaired by Mr. Srinivas Murthy and had three presentations. The first was made by Dr. Tejal Kanitkar from NIAS on the "Avoided Cost of Carbon in the Southern Region and regional electricity supply optimization". The second presentation was made by Mr. S.P. Kumar from the Southern Region Load Dispatch Centre (SRLDC) on the "Infrastructural and Transmission Challenges in the Southern Region". The third presentation was made by Mr. Ravindra Kadam, Advisor for the Central Electricity Regulation Commission (CERC) on the "Regulatory Challenges for Regional Renewable Energy Integration".

The presentation by **Dr. Tejal Kanitkar** of NIAS was part of the ongoing study at the Energy Environment Program (EEP) at NIAS on the "Optimal Electricity Mix for the Southern Region". The southern region in India comprising of five states and one union territory houses more than 49% of the total renewable energy capacity in India. The challenge of renewable energy (RE) integration in the southern region is therefore significant and it is in this context that this work of analysing the optimal fuel supply scenarios for the region was presented by Dr. Kanitkar. The scale of the challenge in RE integration is illustrated here for the state of Karnataka in Figure 3.

The power supply situation of the calendar year 2018 was analysed to estimate the effective cost of carbon reduction being paid by the distribution utilities of the southern region due to environmental policy and regulatory requirements of renewable energy integration. An optimisation model built using the GAMS (General Algebraic Modelling System) computational tool was presented.

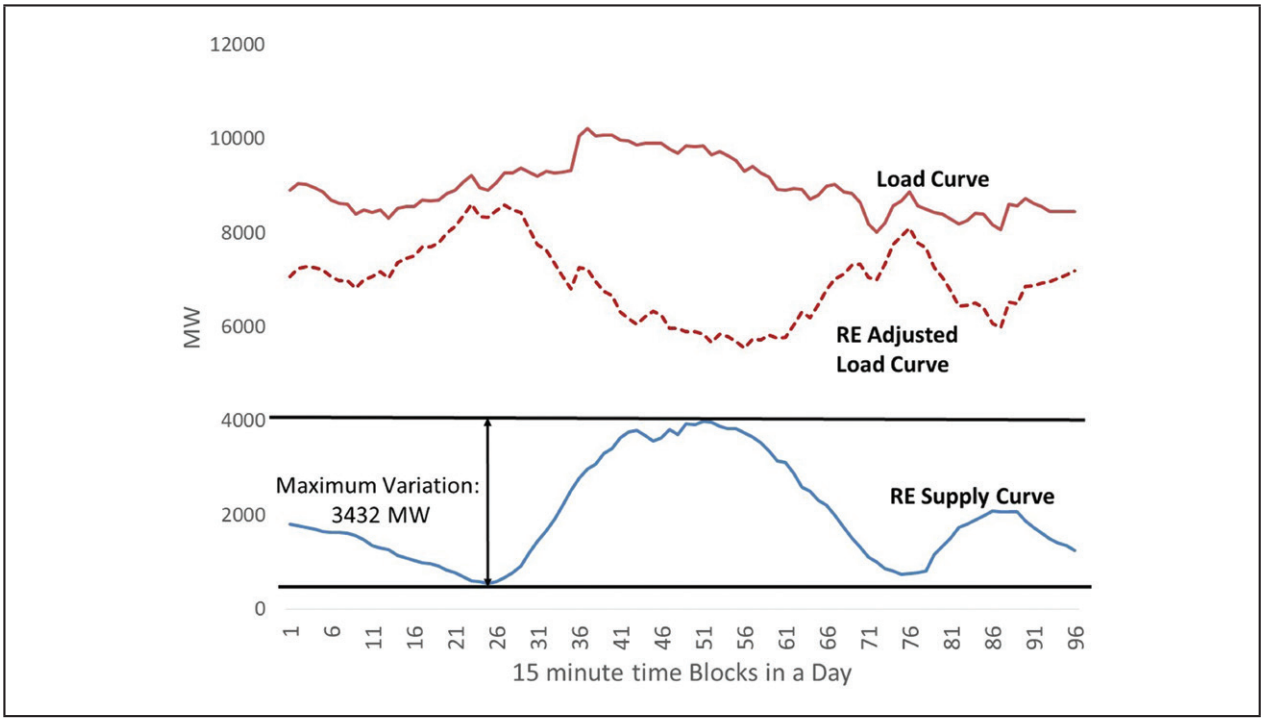


Figure 3. Load Curve and Renewable Energy Adjusted Load Curve for One Representative Day for Karnataka

The results of the model provided a quantitative estimate of the heavy financial burdens that are being borne by states in the southern region for absorbing large amounts of renewable energy generated because of the "must run" status afforded to solar and wind energy capacity. Some of these results for the Southern Indian states are shown in Table 1.

Table 1. Avoided Cost of Carbon and the Total Financial Burden on State Distribution Companies in the Southern Region due to "Must Run" Policy for RE Plants

	Avoided Cost of Carbon (Rs./ton)	Total Financial Burden (Rs. Crore)
Karnataka	132	1567
Telangana	312	1380
Tamil Nadu	133	1977
Andhra Pradesh	202	2418
Kerala*	0	0

In absolute terms Andhra Pradesh bore the highest burden of renewable energy absorption in 2018. The results indicate the need to reduce the burden taken on by the states in the southern region for RE integration by inter-regional transfer of extra renewable energy after the renewable purchase obligations are met. Given the high scale of the burden on utilities, especially in states with large proportions of agricultural consumption, it may also be necessary to review the RPOs that have been set in these states. The high financial burdens on state utilities also indicate the impact of transitioning to a new technology too soon. Dr Kanitkar suggested that the deployment of high amounts of solar energy even at high costs (prior to 2016) coupled with the long-term agreements made for high cost solar power even as costs were reducing, may be responsible, at least in part, for the current crisis facing most distribution utilities of the southern region.

The policy of "must run" status granted to solar and wind plants as well as the renewable purchase obligations (RPO) regime in India, was envisaged and implemented to achieve higher deployment of renewable energy sources. Such policies were required when these sources of energy were more expensive, to incentivize their deployment by assuring developers and banks that investments could be recovered. In the long run, a higher deployment would result in lowering the costs, making the technologies cost competitive and able to compete in the market. The need to promote renewable energy sources is of course clear. From reducing local pollution to mitigating climate change, transitioning out of fossil fuels has both short and long-term advantages in terms of public health, resource sufficiency, and environmental sustainability. These benefits however, are often distributed across populations, both temporally and spatially.

Estimating the social cost of carbon (SCC) is one popular way to quantify the benefits of green investments. SCC is calculated over a period for different assumptions of the extent of climate change mitigation action. Since the benefits accrue over a longer period, this method of calculating the benefits is subject to the assumptions made about discount rates, learning curves for new technology, and imputed costs of the public health impacts of emissions among others (Tol, 2008[1]; Ackerman and Stanton, 2012[2]). The work presented at the workshop does not include forecasting or analysis for future costs of renewable energy as it's deployment increases. This is an analysis done for one year to provide insights into the existing sub-optimality in the power system in Southern India and the impacts of current regulatory requirements on energy costs. Therefore, SCC estimates cannot be directly used to compare the costs discussed in this paper. One must also remember that these are a result of global emissions and not

due to emissions in India alone. These high social costs of carbon are due to higher global emissions than those required to limit global warming to below 2 deg. C, due mostly to other countries and regions. By most estimates, India's Nationally Determined Targets are adequate to meet the 2 deg. C targets.

Another way of putting the avoided cost of carbon in some context however, would be to compare the energy costs in Southern India with some other regions in terms of the economic circumstances in each region. For this purpose, the cost of energy in some of the states in the southern region analyzed in this work were compared to the cost of energy in the US (shown in Table 2).

While the per capita GNI is much higher for the two American states as compared to the Indian ones (Americans earn an income that is 12 times higher than Indians in these states), the difference in electricity tariffs is much lesser. In fact, for commercial and industrial consumers of electricity, the tariffs in Southern India seem to be comparable to the tariffs in Southern United States. The higher cost of electricity in India in comparison to the per capita income in the country is due to a lot of reasons of course, and not just a result of policies for renewable energy generation. India does have to implement policies to incentivize a transition to cleaner energy sources. However, the manner and rate at which this is done, and the impact of such policies should be carefully studied to be able to reduce the burden borne by those who are not primarily responsible for climate change. As per the NIAS research presented in this workshop, stringent implementation of a scientifically-designed RPO regime across the country would lead to a better utilisation of the RE in a more cost-effective manner compared to the current mandate of forcing the DISCOMs to purchase the entire power generated by wind and solar energy sources in the respective states.. For example, the increase in energy costs range from 5-11% because of the 'must run' status for solar and wind energy plants as compared to the baseline. On the other hand, if only the RPOs are made mandatory, the increase in energy costs would be 1.3-4.8% as compared to the baseline, across the states. There would still be an increase, which is inevitable to a certain extent, but a more manageable one.

While the study provides useful insights that can help make the operation of the power sector at the

Table 2. Comparison between the Electricity Charges and Per Capita Incomes for California, Texas, Karnataka, and Tamil Nadu

	Average Per Capita GNI ($/person/year)	Residential Electricity Charge (¢/kWh)	Industrial (¢/kWh)	Commercial (¢/kWh)
California (USA)	35,046	19	12	15
Texas (USA)	29,525	12	5	8
Karnataka(India)	2,500	9 – 10	7 - 10	6 - 15
Tamil Nadu (India)	2,800	6.5 - 9	6 - 9	6 - 11

Data Source: Tariff Orders of the State Electricity Regulatory Commissions for Karnataka (BESCOM) and Tamil Nadu (2018-19); US Energy Information Administration's Monthly Electric Power Industry Report (2019)

[1] Tol, R. S. (2008). The social cost of carbon: trends, outliers and catastrophes. Economics: the open-access, open-assessment E-journal, 2.

[2] Ackerman, F., & Stanton, E. (2012). Climate risks and carbon prices: Revising the social cost of carbon. Economics: The Open-Access, Open-Assessment E-Journal, 6, 10.

current juncture more cost effective and sustainable, it also opens questions as to the robustness of a baseline, based on which forecasting models can then be built. Dr. Kanitkar said that comparing the model against real data suggests prima facie that regulatory constraints and policy interventions have severely reduced the solution space for reasonable cost-based optimization. To be able to build a coherent strategy for expansion of renewable generation, one must first review the robustness of the current technical operations as well as the regulatory and policy regime.

In the discussion that ensued, the importance of using a robust baseline was pointed out since certain years may be outliers because of specific conditions of the power sector in those years. For example, Mr. Murthy who was chairing the session, pointed out that in the year 2018, hydro power plants in Karnataka performed at very low capacities and therefore one should be careful about using this year as a baseline for Karnataka. The most expensive electricity in Karnataka in the year 2018 was from Independent Power Producers which may be due to the signing of many medium and short-term contracts by the State during this year. Prof. P.S. Goel suggested that scenarios built for future projections should also consider novel policies such as time of day tariff and analyse their potential impacts.

Mr. S.P. Kumar, Senior General Manager at SRLDC, made a presentation on "Infrastructural Challenges to Regional Power Planning". The presentation covered the challenges of RE integration with the grid. The difficulty in planning of transmission due to the short gestation period of RE was raised as a point for consideration by policy makers. RE penetration affects the inertia of the system and hence, the shock absorbing capacity of the grid reduces. Mr. Kumar said that currently many lines are kept open due to high voltages, a typical problem of surplus power in the system. Since such large amounts of surplus power are highly uneconomical for the entire system, transmission system planning should now account for the changed scenario in the power sector.

An important aspect that Mr. Kumar stressed on is the importance of lift irrigation systems. The scales of the new lift irrigation schemes are so high that they are imposing very large loads on the power grid at start. The typical operation of a 100 MW lift irrigation pump over a period of time with varying water availability is shown in Figure 4.

There would be a total of around 120,00MW of Lift Irrigation Loads in SR in near future. Given the scale of upcoming projects, it is important to take into consideration their impacts as well as potential for use in grid operation.

He also said that in case grid scale batteries are added to the system in the future, they should be programmed to behave like conventional generation units that provide inertial response.

Mr. Ravindra Kadam, Advisor to CERC made a presentation on "Regulatory Challenges for Regional Power Planning". He said that we need to find ways to incorporate total cost in the system for optimal running in the near future. He also recommended that in the changed scenario in the country, regulators may have to start planning at

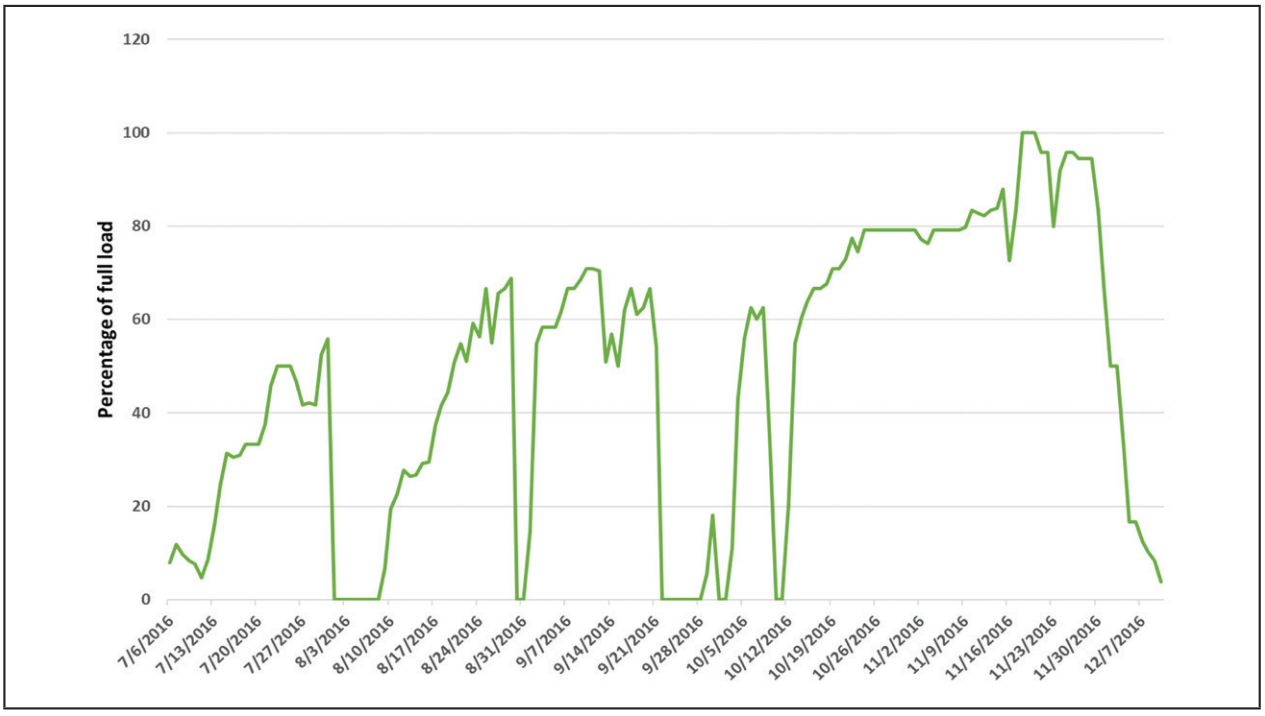


Figure 4. Typical Operation of a 100 MW Lift Irrigation System between 6th July 2016 to 7th December 2016

regional and national levels instead of restricting themselves to the state level. He emphasized that a lot of work is required to create a regulatory framework for a future that has high amounts of renewable energy as attention should be paid to balancing costs required for RE integration.

Mr. Kadam made an important point about the actual costs used while deciding the merit order dispatch as these are month-old costs and not the real-time costs being incurred during generation. He also emphasized on the importance of having a fuel allocation policy as well as a way of ensuring that long term contracts do not jeopardize the financial viability of distribution utilities.

Mr. Soonee made an overall comment and recommendation at the end of this session that since there is very little technical and economic capacity in institutions such as regulatory commissions and even in academia, the Ministry of Power must encourage large scale capacity and institution building exercises in this area.

Session III: Transitions in Conventional power -Challenges and Strategies for the future

Session-III was chaired by Prof. Ravi Grover and presentations were made by two speakers- Prof. R. Srikanth from NIAS on the "Present and Near Future Scenarios for Thermal Power Plants in Southern India" and Mr. S. Chandrashekhar from BHEL, Trichy on "Developments in IGCC (Integrated Gasification Combined Cycle) technology in India".

Prof Srikanth began by providing a broad overview of the power sector in the context of the revised emission norms with respect to particulate matter (PM), SO_x, NO_x, and mercury that are to be complied with by all thermal power plants (TPPs) by 2022. However, only NTPC has placed orders for Flue gas desulphurisers (FGDs) in the southern region whereas the state-owned generation companies (GENCOs) are still assessing the feasibility and economic viability of FGDs which will require significant tariff increases at a time when the DISCOMs are already stressed with total losses projected to exceed Rs.2.6 Trillion in FY 2019-20.

A NITI-Aayog-NIAS-DST workshop chaired by Dr Saraswat on September 17, 2019 had concluded with the following specific recommendations in this regard. These recommendations have been forwarded to policy makers in the Central Government for consideration:

- State owned GENCOs in the southern region must shut down sub-500 MW units that are over 25 years old by December 2022 (or earlier) to save the capital expenditure on retrofitting TPPs with FGDs to meet the revised norms. Higher utilisation of newer, more environment-friendly super-critical TPPs would automatically result in lower CO_2 and PM emissions, since these plants have lower station heat rates and consume lesser amounts of coal for the same amount of power generation. The GENCOs will also be able to avoid costs incurred for life extension of their +25-year old sub-500 MW TPPs beyond 25 years in addition to the costs of retrofitting. The overall water consumption of the power sector will also come down since newer plants designed with higher cycles of concentration consume significantly lesser volumes of water compared to older plants.

- The reduction of SOx emissions as well as reduction in particulate matter (which is a much bigger problem for Indian coal) can be more efficiently achieved by making coal washing mandatory. This has the added advantage of being more energy efficient since the long-distance transportation of large amounts of mineral matter along with the coal will be avoided while the washery rejects (< 65% ash) can also be utilised in Fluidised-Bed-Combustion (FBC) power plants or used in small-scale industries unable to get coal linkages. The ash generated by the FBC plants at the pithead can be backfilled

in closed coal mines nearby, thereby avoiding the problems faced by power plants in ensuring 100% ash utilisation as required by Law. Further, domestic coal (after washing) is more cost effective compared to imported thermal coal which may also contain higher sulphur content. In view of the advantages of using washed domestic thermal coal in TPPs (Table 3), the expert appraisal committee of Ministry of Environment, Forest, and Climate Change (MoEF&CC) has recommended amendment of the environment clearance granted to APGENCO's most modern 800 MW TPP in Vijayawada to permit them to use washed Indian coal in place of imported thermal coal.

- As shown in Figure 5, ambient air concentrations of SO2 around a cluster of pit-head TPPs (with a total generation capacity of 3900 MW) which are using domestic low- sulphur (0.5-0.7%) coal are consistently lower than the National Ambient Air Quality (NAAQ) annual standard of 50 µg/m3. Therefore, the mandate for all TPPs to install costly, imported FGDs irrespective of their location and ambient air SO2 concentrations must be reviewed by MoEF&CC.

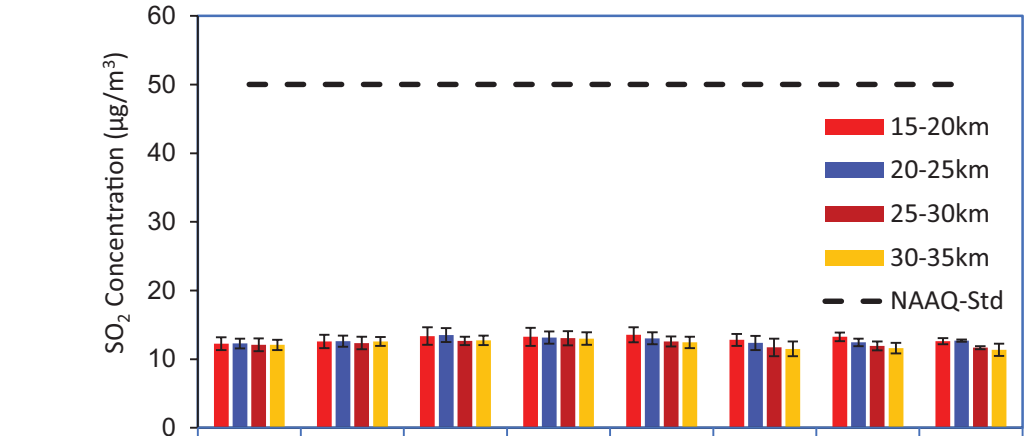
  On the other hand, fine particulate pollutants have a prolonged impact on public health. Therefore, all TPPs in India must expedite the installation of Electrostatic precipitators (ESPs) with a guaranteed efficiency of at least 99.98 percent by delinking the upgradation of ESPs from the installation of FGDs as per the current Central Pollution Control Board (CPCB) deadlines.

In this workshop, Prof Srikanth also presented a transition plan for GENCOs of the Southern Region to comply with the revised emission norms while optimising their expenditure on imported, expensive FGDs which will raise tariffs. The total number of thermal units in Southern Region is approximately 130, out of which 47 +25-year old sub-500 MW units with a capacity of approximately 8 GW are proposed for retirement by 2022. However, the proposed shutdown of these 47 TPP units is largely compensated by the addition of new capacity addition in the form of 10 TPPs (largely, Super-

Table 3. Benefits projected by APGENCO by using washed coal in Vijayawada TPP compared to use of raw coal

Parameter	Unit	Unwashed coal from Talcher	Washed coal from Talcher	Percent Reduction
Coal Consumption (1 x 800 MW SC tech.)	TPD	12,023	10,272	(14.6%)
Ash content of Coal Feed	%	38	34	(12%)
Sulphur content of Coal	%	0.62	0.62	0
Ash generation	TPD	4560	3492	(23.4%)
SO_2 emission	Grams/Second	1726	1474	(14.6%)
NO_x emission	Grams/Second	430	250	(41.9%)
PM emission	Grams/Second	42.3	24.9	(41.1%)
Max Inc. GLC of SO_2	µg/m^3	28.7	24.5	(14.6%)
Max. Inc. GLC of PM	µg/m^3	0.90	0.53	(41.1%)
Max. Inc. GLC of NOx	µg/m^3	7.2	4.2	(41.7%)

Data Source: MoEF&CC, 2019



	2012	2013	2014	2015	2016	2017	2018	2019
15-20km	12.25	12.58	13.37	13.25	13.56	12.81	13.26	12.61
20-25km	12.28	12.64	13.50	13.15	13.04	12.36	12.44	12.69
25-30km	12.09	12.35	12.66	13.06	12.57	11.71	11.94	11.67
30-35km	12.09	12.57	12.74	13.00	12.44	11.50	11.60	11.37
NAAQ-Std	50	50	50	50	50	50	50	50

Figure 5. Ambient air concentrations of SO_2 in the Ramagundam area of Telangana in the direction of most frequent plume travel during the Winter season

critical units) and one 500 MW Nuclear Power Plant (NPP) by 2022. Similarly, the proposed shutdown of five units with a total capacity of 1050 MW between 2022 and 2027 will be compensated by addition of six more efficient and environment-friendly 800 MW TPPs with a total capacity of 4.8 GW and two NPPs with a total capacity of 2 GW. On comparison with the peak demand for the year 2022 from the 19th Electric Power Survey (EPS) report, and assuming that 80% of the peak demand in 2022 will continue to be met by coal and nuclear, i.e. base load plants, enough generation capacity will be available in 2022 despite retiring 47 of the oldest units (listed in Table 4). Any likely shortfall in meeting the peak demand by the year 2027 can be met by inter-regional transfers, i.e. importing energy from the western and eastern regions since the inter-regional transmission capacity is being enhanced to a level of 126.6 GW in 2022, a manifold increase from only 5.75 GW in 2012. Moreover, the actual peak demand by 2022 is likely to be much lower than that projected in the 19th EPS since the gap between the EPS projections and actual data has started widening from the beginning of FY 2019-20. If these proposals are implemented, the costs of meeting the revised environmental norms for the four State GENCOs in the States of Andhra Pradesh, Karnataka, Tamil Nadu, and Telangana while still meeting regional power demands would reduce from more than Rs.8,000 Crores to approximately Rs 4,500 Crores which is a reduction of 43% for financially stressed State GENCOs.

Mr. S. Chandrashekhar made a presentation on the "Developmental challenges of indigenous

Table 4. List of 47 Thermal Power Plants in Southern Region > 25 years old (Total Capacity of 8 GW) which can be retired by 2022 without affecting power availability in the southern region

GENCO	TPP Details	Installed Capacity, MW
APGENCO	Rayalaseema 2x210 MW	420
	Dr NTTPS, Vijayawada 6x210 MW	1260
KPCL	Raichur 4x210 MW	840
TANGEDCO	North Chennai 3x210 MW	630
	Tuticorin 5x210 MW	1050
	Mettur 4x210 MW	840
TSGENCO	Kothagudem 3 x 60 +2x120+2x250 MW	920
	Ramagundam B	62.5
NLC	TPS 1 & 2 7x210+3x100+ 6x50 MW	2070

Coal Gasification technology". He explained the mechanisms behind the operation of Integrated Gasification Combined Cycle (IGCC) plants and the advantages of IGCC plants over pulverized coal- fired boilers. He also provided an overview of the advantages of fluidized bed gasifiers and the gasification development program at BHEL. The key advantage of IGCC technology is the lower coal consumption which reduces energy charges coupled with the ability to extract useful byproducts. The summary of his presentation was that while the design is now ready and can be commercialized, the capital costs can come down only when this technology is adopted by GENCOs in India. Further, the current IGCC designs developed by BHEL for Indian coal are also of smaller scale (~130 MW capacity) and can be scaled up only after this model is commissioned for trails in an operating power plant.

Concluding Session

The concluding session was a roundtable discussion chaired by **Prof. P.S. Goel**, Distinguished Professor, ISRO. He appreciated the participation of all participants which facilitated a healthy discussion and thanked the speakers for their presentations. The concluding session itself was also an extension of the lively discussion on the challenges for the power sector in a future where a higher amount of renewable energy integrated with the grid is likely to be the norm.

The discussions in the concluding section covered a wide array of points, ranging from the need for a scientific analysis to measure the potential of grid connected RE to standalone RE in different contexts and areas, the need for life cycle analysis for all technologies where decisions are made by considering energy returns and energy inputs throughout the life cycle of a technology, to the importance of time-of-day tariff to rationalize electricity demand. Some of the specific recommendations that emerged from the deliberations throughout the workshop are summarized here. These should also be seen as directions in which further work has to be undertaken at NIAS and elsewhere on two fronts – analysis and advocacy.

Policy Recommendations

1. The policy directives in the power sector for the mandated introduction of flue gas desulphurizers (FGDs) across the board in all coal and lignite fired power plants in the country by 2022, irrespective of the age, location, or actual ambient air SOx concentrations in the area around the power plants was primarily guided by environmental concerns. However, retrofitting very old plants with FGDs is an expensive proposition. Therefore, the mandate to retrofit FGDs in all thermal plants must be reviewed after assessing the ambient air concentrations of SO_2 in the older thermal plants that are not located in sensitive, urban, or critically polluted areas. The workshop recommended a more scientific and phased approach which may lead to a sustainable, environment friendly as well as viable power sector. This approach suggests progressive retirement of sub-500 MW plants that are older than 25 years by 2022 instead of retrofitting them with expensive FGDs given the situation of surplus capacity of power in the country. This would lead to better utilization of newer and cleaner thermal plants (and reduce their fixed charges per unit as they will be able to run at higher load factor) and also limit the increase in tariff that would result from the FGD retrofitting. The NIAS research team is also developing specific recommendations with respect to each +25-year-old thermal power plant in the country.

2. Grid balancing in the southern region due to larger proportion of intermittent and variable renewable energy must be facilitated by modernizing existing pumped storage plants (PSPs), and creating new capacity for PSPs in existing hydro projects. The workshop recommended that the Government must invest more in enhancing pumped storage capacity in the Southern and Western regions of the country and explore battery

technology in a circumspect and phased manner as the technology matures and cost reduces.

3. It was also recommended that the Renewable Purchase Obligations (RPO) in each state be reviewed. Currently, states which started deploying renewable energy earlier have higher RPOs and these have resulted in higher costs of energy for the consumers in these states. The RPOs should be determined using multiple considerations, such as the total renewable energy potential in the state, the mix of consumers from different categories (i.e., the number of agricultural consumers, industrial consumers, urban load centres etc.), the pattern of electricity consumption in the state, among other considerations. The regulators must play an effective role in preparing and ensuring the implementation of a standard scientific basis to determine the RPOs.

4. The details of the financial burden currently being borne by the states in the southern region for absorbing a high amount of renewable energy was presented in the workshop. This higher absorption of renewable energy is a result of the "must run" status that has been afforded to solar and wind energy plants. This high cost is largely due to the contracts for power purchase that were signed between the distribution utilities in the state and RE developers before the year 2016. Even though newer plants are cheaper, the average cost of solar energy in all southern states is significantly high. A "must-run" policy for wind and solar plants was necessary for incentivizing these technologies when their deployment was less. At this current juncture, with 49% of the total RE capacity in India being in the southern region, a serious consideration to the financial burden placed on already cash-strapped distribution utilities due to the "must run" policy, is needed. In this context, it was recommended that the "must run" policy be reviewed, and distribution utilities not be mandated to purchase renewable energy beyond meeting the RPOs decided by the state regulators on an objective basis. Concerns about the signals this may send to renewable energy developers can be allayed by making the RPO regime more stringent in all states across the country. There are many states that do not meet their RPOs. The extra energy generated in the Southern region by solar and wind energy plants can be absorbed by distribution utilities outside the region that do not currently meet their RPOs. The possibility of such a system should be seriously considered as currently the extra burden being borne by states due to the "must run" state for solar and wind energy plants ranges from Rs.330 crore to Rs.1500 crore per year across the states of the southern region. In the meantime, the Central Government may also consider special incentives for the DISCOMs in the Southern Region that are procuring higher amounts of RE beyond their respective RPOs and bearing a disproportionate burden of climate change mitigation.

Schedule and Agenda of Workshop

17th January 2020, NIAS, Bengaluru

Session	Time	Speakers	Topics
Tea and Registration 10.00 a.m. - 10.30 a.m.			
Inaugural 10.00 a.m. - 11.30 a.m.	10.30 a.m. - 10.45 a.m.	**Shailesh Nayak,** Director NIAS	Welcome Address
	10.45 a.m. - 11.00 a.m.	**R. Srikanth,** EEP, NIAS	Introduction to the Workshop
	11.00 a.m. - 11.30 a.m.	**Mr. S.K. Soonee,** POSOCO	Keynote Address
Session I: **Power Scenarios for Southern India** *Chair:* **Srinivas Murthy,** Former KERC 11.30 a.m. - 1.30 p.m.	11.30 a.m. - 12.00 p.m.	**Tejal Kanitkar,** EEP, NIAS	Generation Expansion Planning for Southern India
	12.00 p.m. - 12.30 p.m.	**S.P. Kumar,** SRLDC	Infrastructural Challenges to Regional Power Planning
	12.30 p.m. - 1.00 p.m.	**Ravindra Kadam,** CERC	Regulatory Challenges for Regional Power Planning
	1.00 p.m. - 1.30 p.m.	Discussion	
Lunch Break: 1.30 p.m. - 2.30 p.m.			
Session II: **Transitions in Conventional Power: Challenges and Strategies for the Future** *Chair:* **Ravi Grover,** HBNI 2.15 p.m. - 3.45 p.m.	2.30 p.m. - 3.00 p.m.	**R. Srikanth,** NIAS	Thermal Power Plants - Present and Near Future Scenarios for Southern India
	3.00 p.m. - 3.30 p.m.	**S. Chandrashekhar,** BHEL, Trichy	Developments and Challenges for Coal Gasification
	3.30 p.m. - 4.00 p.m.	Discussion	
Concluding Session: **Roundtable Discussion** *Chair:* **P.S. Goel,** NIAS	4.00 p.m. - 5.00 p.m.	Overall concluding remarks, policy recommendations, consolidation of understanding in terms of challenges and potential future strategies	

Document Control Sheet

1	**Document No and Year**	:	NIAS/NSE/EEP/U/WR/07/2020
2	**Title**	:	Optimal Electricity Mix for the Southern Region
3	**Type of Document**	:	Workshop Report
4	**No. of Pages and Figures**	:	20 pages, 4 Tables, 5 figures
5	**No. of References**	:	2 References
6	**Authors**	:	Tejal Kanitkar Nikhil Thejesh, Upasna Ranjan, R. Srikanth
7	**Originating School**	:	Natural Sciences and Engineering
8	**Programme**	:	Energy and Environment
9	**Collaboration**	:	NA
10	**Sponsoring Agency**	:	Ministry of Earth Sciences, Government of India

11 **Abstract:**

A one-day workshop was organized on January 17, 2020 at the National Institute of Advanced Studies (NIAS) on the theme, "Optimal Electricity Mix for the Southern Region." Results of studies undertaken by the Energy and Environment Program at NIAS were presented at the workshop to get feedback and inputs from experts and practitioners in the power sector regarding the theme. The presentations in the workshop included the current overall situation of the power sector, the challenges in renewable energy integration, and ongoing interventions and modeling efforts to better manage a diverse and large Indian power system, with a specific focus on the southern region in India. The overall aim of the workshop was to arrive at a set of suggestions as well as research directions to address the question of economic burdens on increasingly stressed distribution companies in the country as well as to make the best use of available resources in an environmentally sustainable manner.

The range of topics covered during the workshop included, generation expansion planning for India, evaluating the financial implications of emissions reductions in the southern region, optimal thermal energy use to compliment increased infirm power supply in the grid, regulatory and infrastructural challenges to renewable energy integration, developments in clean coal technology with a focus on coal gasification, and strategies for ensuring cost-effective environmental sustainability in the coal and lignite fired power plants. This report contains a summary of the deliberations and the key recommendations that are worthy of consideration by policy makers to transition towards an optimal energy mix for the southern region. Similar studies are being undertaken by NIAS for the overall electricity sector in the entire country.

12 **Keywords:**
Renewable Energy, Renewable Purchase Obligations, Energy Transition, Thermal Power Plants, Southern India

13 **Security Classification** : Unrestricted

National Institute of Advanced Studies

The National Institute of Advanced Studies (NIAS) was conceived and established in 1988 by the vision and initiative of the late Mr. J.R.D. Tata primarily to nurture a broad base of scholars, managers and leaders to address complex and important challenges faced by society through interdisciplinary approaches. The Institute also engages in advanced multidisciplinary research in the areas of humanities, social sciences, natural sciences and engineering, as well as conflict and security studies.

Energy and Environment Programme
National Institute of Advanced Studies
Bengaluru, India