International Journal of Electrical and Electronics Research ISSN 2348-6988 (online)
Vol. 7, Issue 3, pp: (52-57), Month: July - September 2019, Available at: www.researchpublish.com

GENERATION OF ELECTRICITY IN INDIA: PRESENT STATE AND FUTURE SCOPE

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Abstract: **India's energy sector is one of the most critical components of an infrastructure that affects India's economic growth and therefore is also one of the largest industries in India. India has the 5th largest electricity generating capacity and is the 6th largest energy consumer amounting for around 3.4 % of global energy consumption. India's energy demand has grown at 3.6 % pa over the past 30 years. The consumption of the energy is directly proportional to the progress of manpower with ever growing population, improvement in the living standard of the humanity and industrialization of the developing countries. Very recently smart grid technology can attribute important role in energy scenario. Smart grid refers to electric power system that enhances grid reliability and efficiency by automatically responding to system disturbances. This paper discusses the new communication infrastructure and scheme designed to integrate data.**

Keywords: **India's energy sector, India's economic growth, electric power system.**

1. INTRODUCTION

Electricity infrastructure and production are important for a developing economy like that of India, which with apopulation of 1.2billion and an area of 3.29million km2 is the 7th largest country in the world. With a GDP of US $2.3trillion in 2015 and anaverage GDP growth of 7% per year ,the growth of the electricity sector will be important to sustain the economic output of the country. Total electricity generation in India during 2015 was 1300 TWh from both utilities and non-utilities in 2013, the electricity consumption from all sectors was and with an average growth rate of 9% and it was estimated to be approximately 980TWh in 2015. The electrical network suffers from transmission losses of approximately 25%. In 2015, per capital electricity consumption was 746kWh. Since per capital electricity consumption has a positive relation with GDP per capital, it can be used as a standard for judging the stage of economic development. Most countries with a GDP per capital of more than US$10,000 have an electricity consumption of more than 4500 kWh per capita.

There are few exceptions to this case, depending on the structure of the economy in that country.

It can been expected that with the growth of the Indian economy, the GDP per capital will improve, and hence, there will be a need for more electricity in the future. In this regard, forecasting the electricity demand isvital as it can help the decision.

India is the **sixth largest in terms of power generation**. About **65%** of the electricity consumed in India is generated by thermal power plants, **22%** by hydro electric power plants, **3%** by nuclear power plants and rest by **10%** from other alternate sources like solar, wind, biomass etc. **53.7%** of India's commercial energy demand is met through the country's vast coal reserves. The country has also invested heavily in recent years on renewable sources of energy such as wind energy. As of **March 2011**, India's installed wind power generation capacity stood at about ***12000 MW***. Additionally, India has committed massive amount of funds for the construction of various nuclear reactors which would generate at least 30,000 MW. In July 2009, India unveiled a **$19 billion plan to produce 20,000 MW of solar power by 2020 under National Solar Mission.**

2. ELECTRICITY GENERATION IN INDIA

Electricity production in India is mostly achieved through coal thermal power plants Although there have been efforts to diversify the options, particularly in the case of renewable energies coalremains the dominant source of electricity in the country. Since 2000, the share of electricity production from coal has been slowly increasing; it was 68% at the start of the millennium and has increased to 73% in 2013.

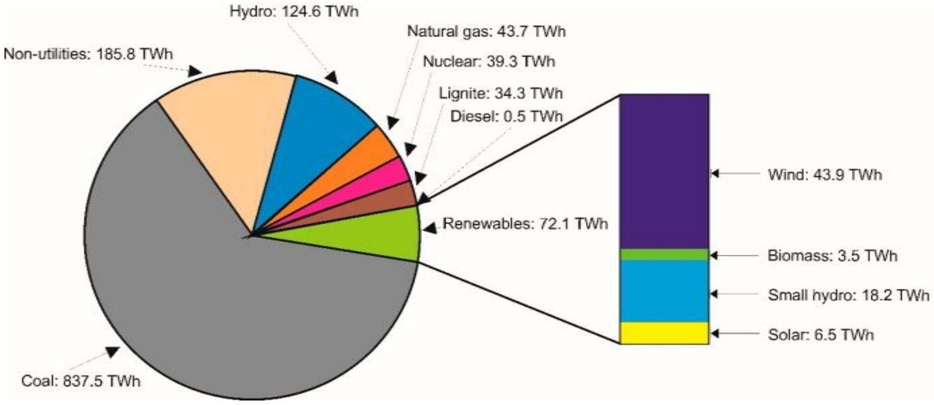

Figure 1: Electricity mix in India 2015

The percentage actual shares of all other energy sources, except renewables, have decreased during that time. In 2015, India generated a total of 1078 TWh from coal, natural gas, oil nuclear and hydropower sources. Renewable and alternative electricity in the form of solar, wind,biomass and small hydropower (less than 25 MW) plants arealso making big progress. These types of electricity source were estimated to generate approximately 70 TWh of electricity in 2015. Non-utilities or independent power producers have also been growing at a rate of 9% over the years.

3. ELECTRICITY DEMAND IN INDIA

India's electricity consumption was 980 TWh in 2015 and has been increasing at an average rate of 8.84%. Electricity consumption is highest in the industrial sector(Figure3), which in 2015, was estimated to consume 450 TWh(46%) and shows the highest growth in electricity consumption (11%). Some of the most important industries for the Indian economy are the steel industry; aluminum industry; cement industry; petroleum industry; pulp and paper industry; fertilizer industry; micro, small and medium enterprises and otherindustries (they are listed as important because each of themhave their own ministry). Crude steel production in India in 2015 was 89 million tons , and there has been a gradual trend in decreasing energy intensity per ton of crude steel produced. From an average of 6.3 GCal (26.36 TJ) in 2013, the strategic goal is 4.5 GCal (18.83 TJ) per metric ton of crude steel by 2025-26. The aluminum production in India was 2.36million tons and the electricity intensity per ton produced was estimated to be approximately 14,000–17,000 kWh Cement production in India was 300 million tons in 2015 and the electricity intensity per ton was 80 kWh.

The petroleum industry is one of the largest industries in India, producing 221 million tons of various petroleum products . India's oil refining capacity is 5th in the world behind the United States of America, China, Russia and Japan. India's specific energy consumption per ton of production is also improving from 76.4 MBTU/BBL in 2006 to 70.7 MBTU/BBL in 2008. The pulp and paper production in India was approximately 7 million tons in 2010 and is showing a growthrate of 8.1%. Most of the energy used in this industry is in the form of process heat, and approximately 25% of the power comes from electricity Micro, small and medium enterprises (MSMEs) form the backbone of the Indian manufacturing economy, contributing to approximately 8.7% of the GDP. These enterprises account for 45% of the manufacturing output and 40% of exports. The independent nature of this sector makes it free from outside control and decision making. The energy consumed by this sector was estimated to be ca. 275 TJ based on a survey of 43 enterprises.

In 2015, the domestic sector was estimated to consume 213 TWh.and is currently the 2nd highest consumer. This is to be expected withIndia's high population. In 2011, there were a total of 240 million households in India in the domestic sector, of which 67% are in the ruralsector. There has been a larger increase in households in the urban sector compared to the rural sector, which can be attributed to rapid urbanization and people moving from rural areas to urban areas. In 2011, 55% of rural households were electrified compared to 93%of households in the urban sector. Therefore, is makes no sense to compare India with elasticities of electricity demand of developed countries.

Electricity consumption varies from 1200–2200 kWh/ton of paper. Fertilizer production in Indiawas 32.5 million tons in 2013. This industry is an energy- efficient sector consuming approximately 29 GJ/Mt owing to the best practices adopted in gas-based plants. Approximately 80% of the energy used was in the form of natural gas and crude oil[10].

The agriculture sector was estimated to consume 167 TWh in 2015and is the 3rd highest consumer with a 17% share India has 125 million hectares of land used for agriculture and approximately 50% of the land is irrigated. Since 1991, the land use for agriculture remained roughly the same, while electricity consumption increased over the same period.This increase may be due to the increasing use of irrigation over agricultural lands to provide better yields (which has improved almost 2- fold per hectare since 1991).In 2015, the commercial sector was estimated to consume 86 TWhof electricity. This sector is the 4th highest consumer (9%), but the electricity consumption in this sector is increasing at a higher rate (8.82%) compared to those of the domestic (7.89%) andagricultural (6.59%) sectors [12]. Total commercial floor space was estimated to be 660 million square meters in 2010 [13] and is experiencing an average growth of 5% every year. The commercial sector ranges from wholesale trade to public administrative buildings to buildings used for education and hospitals. USAID ECO-III Project [13] also estimated the electricity intensity per square meter for every sector under the commercial category. The railways sector was estimated to consume 15.5 TWhin 2015 [12]. In 2012, passenger kilometers travelled were 1000 billion km, while freight traffic was 975 million km. Out of this, 50% was through electrified trains (both goods and passenger trains)[14]. Finally, the remainder of electricity consumption was from other unorganized sectors, and it was estimated that they consumed 46 TWh in 2015 [12] and have an average annual growth of 4.75%.

4. ENERGY AND CLIMATE: STATE OF PLAY

The world is at a critical juncture in its efforts to combat climate change. Since the first Conference of the Parties (COP) in 1995, greenhouse-gas(GHG) emissions have risen by more than one-quarter and the atmospheric concentration of these gases has increased steadily to 435 parts per million carbon-dioxide equivalent (ppm CO2-eq) in 2012 (EEA, 2015).1 The International Panel on Climate Change (IPCC) has concluded that, in the absence of fully committed and urgent action, climate change will have severe and irreversible impacts across the world. The international commitment to keep the increase in long-term average temperatures to below two degrees Celsius (2 °C), relative to pre-industrial levels, will require substantial and sustained reductions in global emissions

The long lifetime of greenhouse gases means that it is the cumulative build-up in the atmosphere that matters most. In its latest report, the Intergovernmental Panel on Climate Change (IPCC) estimated that to preserve a 50% chance of limiting global warming to 2 °C, the world can support a maximum carbon dioxide (CO2) emissions “budget” of 3 000 gigatonnes (Gt) (the mid-point in a range of 2 900 Gt to 3 200 Gt)2014), of which an estimated 1 970 Gt had already been emitted before 2014. Accounting for CO2 emissions from industrial processes and land use, land-use change and forestry over the rest of the 21stcentury leaves the energy sector2 with a carbon budget of 980 Gt (the midpoint in a range of 880 Gt to 1 180 Gt) from the start of 2014 onwards. The carbon legacy that is locked-in by new development of fossil-fuelled energy infrastructure underlines the importance that attaches to success in achieving a step change in efforts to contain GHG emissions in the COP21 meeting to be held in Paris in December 2015.

The path towards a new agreement at COP21 began in 2009 with the attempt at COP15 in Copenhagen to develop a successor to the Kyoto Protocol, which was negotiated in 1997 and is still in effect but is expected to cover only 10% of global GHG emissions by 2020. While COP15 failed to achieve a binding treaty, it did result in some pivotal political outcomes: an agreed definition, subsequently universally adopted, of the objective to keep the long-term global average temperature increase below 2 °C; the principle that both developed and developing countries should undertake nationally appropriate actions to reduce emissions; and a commitment to make available $100 billion per year of public and private climate finance to developing countries by 2020, mainly through the Green Climate Fund.3 Moreover, under the Copenhagen Accord, countries accounting for around 80% of GHG emissions made pledges to mitigation goals and actions for the period to 2020, marking a major improvement on the Kyoto Protocol. Negotiations towards a new legal agreement for the post-2020 period started in 2011 at COP17 in Durban, South Africa. The new agreement is to apply to the 196 Parties to the UNFCCC and to be adopted by 2015. By 2014 at the time of COP20 in Lima, Peru, the new agreement was beginning to take shape. Countries agreed to communicate so-called Intended Nationally Determined Contributions (INDCs), their pledged actions under the new agreement, well in advance of COP21 and in a manner that is clear, transparent and facilitates understanding. All UNFCCC Parties will come together at COP21 in December 2015 in an attempt to bring these negotiations to a successfulconclusion.Astrongagreementisrequiredtoprovideaclearsignal that all countries are committed to the todecarbonisation and to convince energy sector investors that they need to adopt low-carbon options. The submission by individual countries of their own climate contribution to the 2015 agreement (INDCs) will form the core "bottom- up" element of the climate deal to be agreed at COP21. The INDCs will apply to a period starting in 2021 and are expected to represent "a progression beyond the current undertaking of that Party" (UNFCCC, 2015).

5. DESIGN AND PROCEDURE METHODOLOGY

To respond to the climate change mitigation quest, massive amounts of clean energy need to be introduced in the coming decades. The magnitude of the changes needed to meet the targets of the Paris Climate Accord from December 2015 represents a major transition from the present fossil-fuel based energy economy to a clean-energy one, which is almost CO2 free. The changes ahead are not only about technology changes, but include major societal changes as well turning the changes into a major social-technical transition. This paper adds to the literature to better understand and model the transition from the present energy system to a sustainable one in line with the ambitious climate goals (IPCC, 2014). Two strands of literature on energy transitions have evolved in parallel. The first deals with socio-technical analyses of energy transitions including transition pathways (Geels et al., 2016; Geels, Berkhout and Van Vuuren, 2016; Grubler, Wilson and Nemet, 2016; Sovacool, 2016). The second one is on quantitative modelling of energy systems on a macro scale using integrated assessment models that address multiple societal objectives (van Vuuren et al., 2015), agent-based modelling of complex systems (Bale, Vargaand Foxon, 2015; Ringler, Keles and Fichtner, 2016), or technologically detailed energy system optimisation models such as ETP-TIMES (Karlsson et al., 2016)and Balmorel (Kirkerud et al., 2014). Some recent studies (Holtz et al., 2015; Turnheim et al., 2015; Cherp et al., 2018) also discuss the ways of integrating or bridging the two distinct analytical approaches, often labelled as 'socio-technical' and 'technoeconomic' They address the former one's focus on socio-technical variables (institutions, actors, values, technology innovation, etc.) and theirinteraction over longer time periods (decades) at multiple levels and scales. The latter one emphasizes detailed technological and economic variables, andsystem interactions, also over decades, in a formalised quantitative framework. In addition to these two main approaches, there exist alternative perspectives identified by Turnheim et al. (2015) and by Cherp et al. (2018). The first article highlights the initiative-based learning approach that stresses the influence of transition pathways of real-world experimentation, learning by doing, actor involvement, stakeholder relevance, and local level implementation..

The latter identifies political perspectives that address the role of institutions, the state, international relations, and special interests, among other political economic factors. 2 In the light of these recent advances, and to add new insights, this paper aims at analysing how quantitative modelling of energy scenarios as sustainable energy transition pathways can be made more realistic and less linear, accounting for insights from the socio-technical and relatedliterature above. The proposition is that an enriched modelling approach should not focus just on technology development and deployment, but also on feedback loops, learning processes, the importance of policy and governance and of behavioural changes, interlinkages between the energy and other economic sectors, and infrastructure development. We link our analysis in particular to variable renewable electricity generation (VRE) such as wind and solar power, which are the key energy production technologies in the clean energy transition (IEA, 2017). We focus on the Nordic region, in which wind energy may play a more importantrolethanonaverageglobally,whichmayalsointroducemajor challenges with balancing the power system demand and supply.

The technological quest may therefore not only be in the clean energy production, but actually in approaches, which increase the flexibility of the whole energy system so that the power demand and supply are matched and that the energy system can accept clean power. This in turn indicates a major systemic change in the energy system as well. We consider increasing the flexibility of the energy system as an important element in the energy transition (Koskinen and Breyer, 2016; Child et al., 2018) and as an important enabler of the transition, for which reason it is also given attention in our analysis. Finally, the paper will also provide an assessment on how well quantitative modelling approaches other than integrated assessment models and optimisation energy models are suited to consider sociotechnical variables and deal with highly complex dynamic systems

(Holtz et al., 2015). The focus here is on system dynamics modelling (SDM) (Blumberga et al., 2018). Application of system dynamics for modelling of energy transitions is analysed by describing the differences between system dynamics and a traditional modelling approach that uses econometric and linear programming methods. A conceptual framework, represented by causalrelations between elements of a system for this type of modelling is provided in Section 5. The remainder of the paper is organised as follows. The next section outlines different theoretical perspectives on energy transitions and theanalytical challenges associated with each one, and states the research questions. Section 3 describes the different steps of the methodology developed in the paper and outlines the main elements in system dynamics modelling of sustainable energy transitions. Section 4 discusses concepts .

6. THE NEED FOR AN "INDIA" ENERGY SECURITY "INDEX".

Import dependence has traditionally been used as the soledeterminant of energy security for India. This does not do justice to the myriad challenges of India's energy landscape—such as access, affordability and sustainability. Also, it does not allow for appropriate trade-offs between various objectives (e.g., greater renewables usage improves sustainability but could compromise affordability or lead to lower reliability if grid integration is poor). Several agencies (e.g., IEA, World Energy Council, US Chambers of Commerce, World Bank, ERIA) have broadened the definition of energy security to include fuel mix, sustainability and economic viability. Should India adopt one of these indices to measure its energy security? We believe that India needs its own tailored index that takes into account India's challenges. Such an index shouldalso measure whether India is meeting the energy needs of all its citizens in an affordable and environmentally sustainable manner.

7. RESULT AND DISCUSSION

The Indian electricity sector is witnessing a major transformation in respect of demand growth, energy mix and market operations. Various socio-economic factors and technology developments are contributing to this. A detailed and critical assessment of the emerging scenario is of paramount importance for the sustainable development of the sector. A macro-level assessment in stylised scenarios up to 2029–30 are covered in the present study.

Analysis of the demand during the past 15 years shows that the demand is strongly influenced by various economic factors. These are also found to vary among states, depending upon the economic activity predominant in that state warranting detailed econometric studies for the states. The present study has focussed on assessment of electricity demand at all India level on the premise that the total electricity consumption in a year will depend upon that year's GDP along-with previous years' electricity consumption. Empirically, data on all India electricity consumption and GDP has shown a high correlation coefficient of more than 95%. Based on the above, all India level demand projections in the stylised scenarios upto 2029–30 have been carried out using the electricity demand and GDP datafrom 2001–02 to 2015–16. The impact of future end-use energy efficiency improvements, electrification of new households and additional requirement for electrified road transport, which may not follow the past trend has been accounted for exogenously.

These demand projections may go up or down depending on the success of the UDAY programme, Make in India initiative, deceleration in the use of captive power, energy efficiency, DSM programs, etc.

The energy mix is also projected to undergo radical changes with increased focus on (especially solar and wind) and considering the operational and environmental issues related to coal power plants. The increasing penetration of solar and wind (which have inherent high intermittency and variability) would no doubt present a number of challenges in respect to planning and operation of power systems. Timely strengthening of the grid infrastructure and

provision of adequate balancing and storage capacity, ensuring requisite flexibility in ramping up and down, improved forecasting of RE power as well as demand, improved financial health of utilities would be key factors in this context. Taking these into account two scenarios of RE development have been considered in this study. The HRES considers capacity increase from the prevailing level of about 50 GW to 175 GW in 2021–22 and 275 GW in 2025-26. The LRES considers capacity additionof75 GW during thenfirst 5 years (reaching a level of 125 GW) in 2021-22 and 100 GW in the next 5 years (reaching a level of 225 GW) in 2026–27.

The results indicate that the energy that would be available from RE sources, storage hydro, nuclear and gas plants (existing as well as those planned/committed) would suffice for meeting the remainder of the demand for electricity at the national level during the next 7-8 years. This would in other words mean that no new coal plants would be needed and the plant load factor (PLF) of coal based plants would be in the range of 78-80% in 2024–25 and 2025–26.

The type of new capacity which will be required in the following years would depend upon how the aforementioned challenges get addressed and cost economics of storage technologies (which could increase the dispatchability of RE plants). In the HRES, it is assumed that the remainder of the demand in the subsequent TRANSITIONS IN INDIAN ELECTRICITY SECTOR 2017–2030 years (over and above what can be met from plants already considered up to 2016–27) would be through RE capacity additions, on the premise that the price of RE+ balancing electricity would be about `5 per kWh and competitive with the price of electricity from coal. In this scenario, the share of electricitygenerated fromREwouldincreasefromthepresentlevelof~5.6%to ~34% in by 2030 and the shareof coal-based electricity generationwould reduce from ~ 73 % to ~56%.In the LRES the additional requirement of supply beyond2025–26 is assumed to be largely met by new coal capacity (and other conventional sources including gas depending upon the cost economics at that time), and to a limited extent from new RE capacity.

The evolving scenario being dynamic, periodic, preferably annual, assessment is imperative to take stock of the emerging scenario by evaluating the evolving demand and supply trajectories, technological developments, learning from global and Indian experiences in the ensuing period as well as factoring in various technoeconomic considerations and above all the financial health of the utilities.

8. CONCLUSION

In present time, whole world is suffering from global warming, dense fog due to pollution, acute disease like cancer due to ozone depletion pollution. Root cause of all the above problem is burning of fossil fuel(coal, diesel, petrol). To save the environment for our upcoming generation, we have to follow the renewable energy sources like solar, wind, geo-thermal and tidal.

The current Northwest energy system runs primarily on three different sources of energy: coal, hydro, and petroleum. Either coal or hydro supplies most of the electricity in every state in the Northwest. Massive amounts of energy are consumed from petroleum sources as well, however, in non-electrical uses such as transportation. Unfortunately, all three of these energy sources have drawbacks. Coal and petroleum are fossil fuels and therefore inherently limited in quantity. These fuels are also highly polluting, and cannot form the basis for a completely sustainable society. The other major source, hydroelectric power, has also come under fire from various groups due to adverse effects it imposes upon local aquatic life. The issue of how hydro should be weighed in terms of the benefits it brings with greatly lessened greenhouse gas emissions yet the drawbacks it presents with possibly causing the near extinction of several aquatic species is something we would like to continue exploring in the future. Technical impact information as well as sociological studies should both be used to shed more light on this delicate issue

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