Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 2, No. 1, February : 2023

EMERGING TECHNOLOGIES IN ELECTRICITY DISTRIBUTION CONTRIBUTING SUSTAINABILITY.

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Abstract— India is currently the fifth biggest economy and touted to be third biggest economy by 2030 with GDP(Gross domestic product) of USD 7.5 trillion overtaking Japan and Germany. India has been posting a year-on-year growth of more than 6%. By 2025, India is expected to have more than 250 Unicorns or start-up with valuation of 1 billion or above. For Indian companies to enter in elite class of Fortune 500, it is pertinent to meet the global standards of quality, safety and ESG(Environmental, Social and Governance). A good ESG strategy ensures a boost to brand image, earn investors and customer confidence, reduce environmental and legal obligations and related overheads, improve asset management and overall profitability. ESG benchmarking allows stakeholders and companies to set a tone for improvement, identify impediments and chalk-out future strategies and create long term business value without any adverse effect on environment and society.

Environment is the backbone of sustainability in view of global warming and its long-term effect on humanity and flora and fauna. Electricity sector being the most energy intensive Industry is relevant to emerging technologies which can ensure and establish a greener and sustainable tomorrow. For few years, Electricity distribution sector is witnessing the new trends like use of bio-degradable transformer oil(Ester oil), Green gas for switchgears in place of SF6, Solar rooftop PV generation to reduce carbon footprint of utility, Reliability centered maintenance for assets to reduce consumption of resources like mineral oil, SF6 gas etc. Avenues like use of ethanol blended petrol for operation, use of LED lamps in place of HPSV lamps are also being availed by leading utilities in India. An effort is made through this technical paper to touch upon emerging trends in electricity distribution, associated challenges and mitigation.

Keywords— GDP, ESG, Sustainability, Ester oil, Solar PV, Ethanol blending

I. INTRODUCTION

India has been witnessing the windfall in IT, Infrastructure, energy sector, manufacturing and Bio-medical. As per the report of Morgan Stanley[1], it is envisaged that India will be the third largest economy at the end of 2030. India's GDP shall surpass more than twice the size of current GDP by 2031. The unprecedented rise of Indian economy is the result of liberalization, export-oriented approach, direct foreign investment due to high confidence level of investors and young and cheap labor. Young demographic of India implies that in next year, about quarter of the global workforce shall be supplied from India[2]. 2020-2050 is the next Indian golden age wherein the working population will continue to dominate. The has been witnessed for China in past which has contributed to its phenomenal growth as next superpower during last 30 years.

ESG(Environmental, Social and Governance) framework allows organizations to exhibit to their shareholders and investors how they manage risks and opportunities beyond environment and carbon neutrality[3]. ESG benchmark organizations and emphasize the sustainability of organization in terms of

risks envisaged in future on account of changing regulatory, climatic and social demographics besides providing global recognition. ESG disclosure as of now is not mandatory through any statute thoughdriven by market mandates and organization culture and aspirations. ESG framework is adopted by leading Indian organization to compete in global market and onboard big investors across the boundaries of nation.

II. ESG FRAMEWORKS, ENVIRONMENTAL RISKS AND OPPORTUNITIES

An ESG framework only provides an outline of disclosure and not the complete methodology for data collation, compiling and reporting. ESG standards are specific and set criterion for reporting. They also mandate the information collection and reporting methodology. ESG framework[4] is grouped into three categories namely Voluntary disclosure framework, guidance framework and third-party aggregators.

A. Voluntary disclosures frameworks

Under this framework, an organization declares its ESG related policies, the practices being followed and related performance data. Most popular voluntary disclosure frameworks are CDP(Carbon disclosure project), DJSI(Dow Jones Sustainability Indices) and GRESB(Global Real Estate Industry Benchmark). Main focus areas through these frameworks are organizational carbon footprint, water security, occupying commercial and office space's ESG data, assets and real estate portfolios etc.

B. Guidance frameworks

Through this framework recommended methodologies and outlines to identify, administer and publish the ESG performance are prescribed. The very common guidance frameworks are SASB(Sustainability Accounting Standard Board), TCFD(Task Force on Climate related Financial Disclosures), CDSB(Carbon Disclosure Standard Board), GRI(Global Reporting Initiative) and IIRC(Internal Integrated Reporting Council). Focus areas through this framework are financial performance related critical ESG issues, governance and transparency, strategy and risk management and baseline for corporate sustainability which can be referred across industry and countries.

C. Third Party Aggregators

Through this framework organization performance is assessed through publicly available information like company filings in regulatory and other forums, websites, annual reports and CSR reports. Main players under this framework are Bloomberg Terminal ESG analysis, ISS ESS(Institutional Shareholder services) and Quality Score(ISS), MSCI and Sustainalytics. Focus areas are organizational performance assessment through available public domain resources.

As per the ESG survey[5] for Top 100 listed companies in India(excluding public sector undertakings and government banks), the major findings were related to lack of consistent and comparable disclosures, low divergence between ESG parameters among high scoring companies and poor performance of E & S factors as compared to G factor suggesting regulatory gap.

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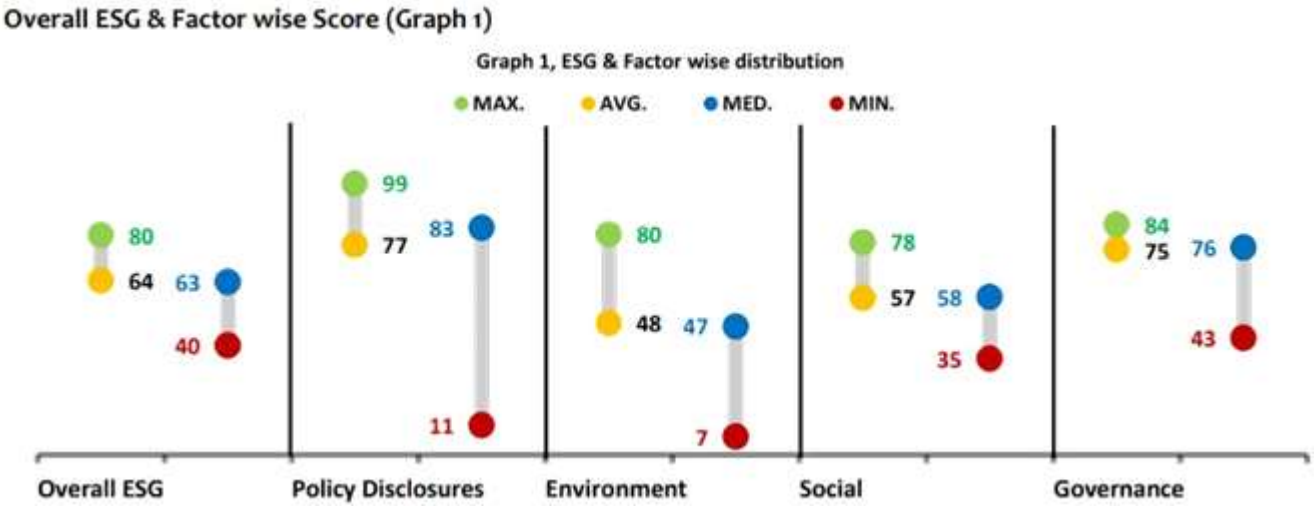

Fig 1.1 ESG Score distribution (Credit:ESG report by SES)

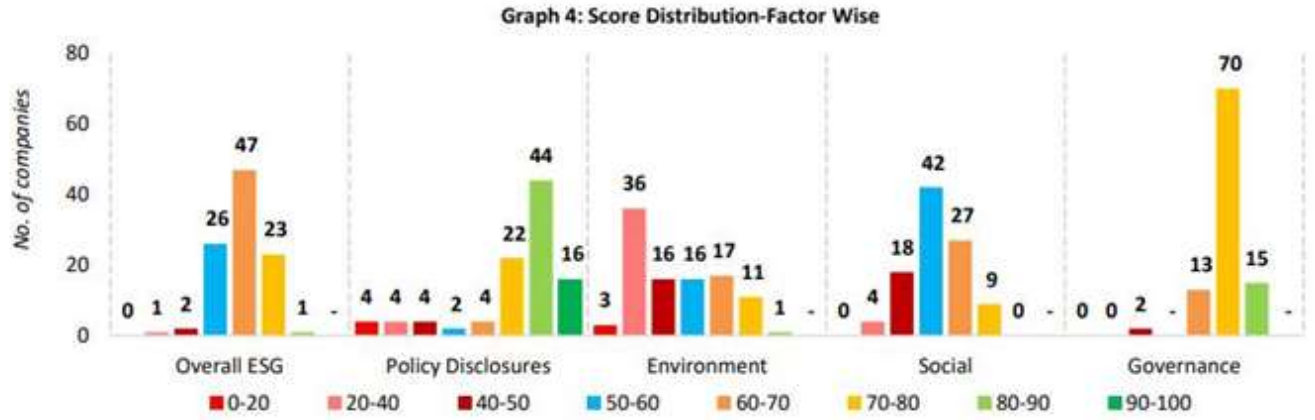

Fig 1.2 ESG Score distribution – Factor wise vis a vis Companies(Credit:ESG report by SES)

Only two power sector companies, namely Adani Transmission Limited and Adani Green are in the top 100 companies as per the said report. The electricity sector being a highly energy intensive industry requires a greater focus in terms of environment factor under ESG framework. In global energy transition, India's T&D sector is going to play a significant role. T&D sector is undergoing a major transformation considering huge capacity addition, upgradation of networks through regulatory approved DPRs, Open access regulations and multifold increase in renewable capacity and technology upgradation. Hence to benchmark the performance of Indian Electricity utilities, ESG performance and in particular environment performance shall be pertinent. Environmental Risks for Electricity Distribution sector as envisaged are as below:

A. Impact on global warming due to GHG(Green House Gases) in operation
B. Level of Energy intensity as per mix of renewable and non-renewable sources
C. Impact on biodiversity due to use of hazardous products/non-biodegradable products in operation
D. Sensitivity to extreme weather events : Incremental cost or potential physical impact on assets[6]

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III. ESG Environment factor for Electricity Distribution Utilities - opportunities

A. Green Gas in place of SF6 gas

Since 2000, nineteen out of 22 years have been the warmest years recorded in modern history, which is result of Greenhouse effect. Greenhouse gases (GHGs) are responsible for climate change. Sulfur hexafluoride (SF6), an insulating gas is used in high-voltage(>66 kV) and medium-voltage(33/11 kV) switchgears. It is estimated that it has 23,500 times more impact than carbon dioxide (CO2) to the greenhouse effect. Further it has a long stable life and can sustain 3,200 years in atmosphere[7]. In view of it, efforts have been made by various OEMs and researchers to find reliable and sustainable substitute of SF6. GE(General Electric) has come up with g^3 solution, which is a mixture of O_2, CO_2 and Novec™ 4710 fluoronitrile introduced by 3M company[8]. Many grid operators in Europe have chosen g^3 to reduce the environmental impact of their operation. This has also reduced their physical and economic footprint by way of engineering interventions and compliance management.

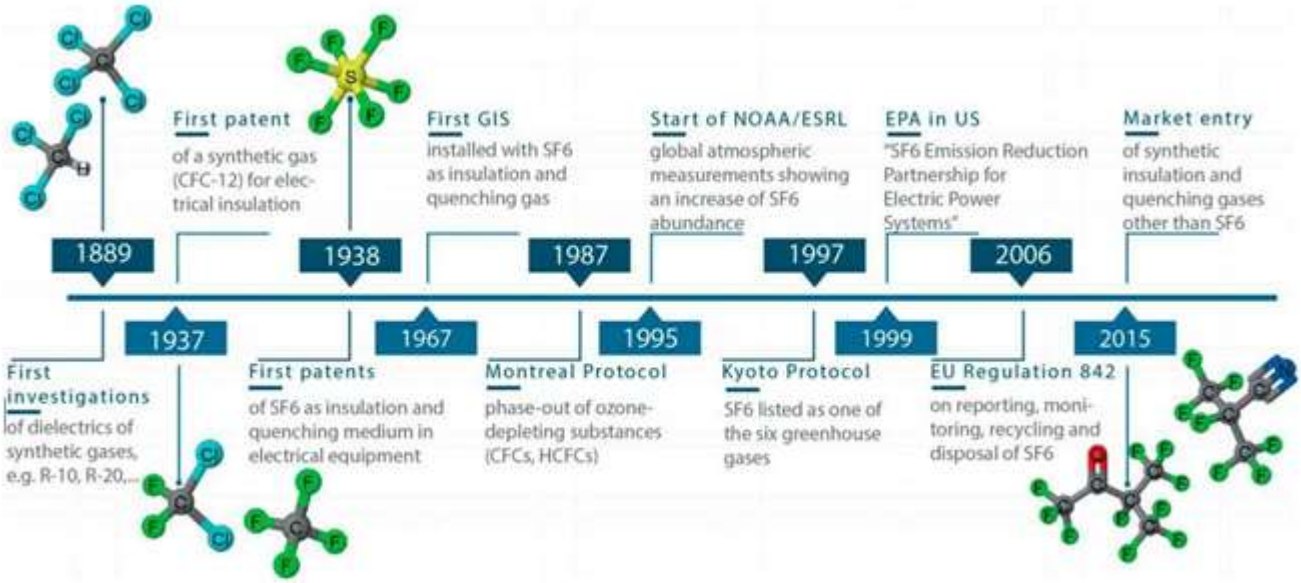

Fig 1.3 Evolution of Sf6 alternate gas (Credit: www.switchgearcontent.com development SF6 alternative gases in switchgear)

Compounds		Chemical abstracts service (CAS) Nr° [1]	Concentration, %	Concentration, ppm
CO_2 (*carbon dioxide*)	g^3	124-38-9	93.50	935,018
$(CF_3)_2CFCN$ (*heptafluoroisobutyronitrile or Novec 4710*)		42532-60-5	4.06	40,600
CO (*carbon monoxide*)	by-products	630-08-0	2.4	24,000
CF_2=CFCN (*perfluoroacrylonitrile*)		433-43-2	0.013	130
CN–CN (*ethandinitride*)		460-19-5	0,0065	65
CF_3–CF_2–CN (*pentafluoropropionitrile*)		442-04-08	0.006	60
CF_3–CN (*trifluoroacetonitrile*)		353-85-5	0.0058	58
$(CH_3)_2SiF_2$			0.0052	52
COF_2 (*carbonyl fluoride*) + C_3F_8 (*octafluoropropane*)		353-50-4 + 76-19-7	0.0014	14
$(CF_3)_2CHCN$ (*hexafluoroisobutyronitrile*)		NA	0.00019	1.9
$(CF_3)_2C=CF_2$ (*perfluoroisobutene*)		382-21-8	0.00013	1.3

Fig 1.4 Composition of g3 – an alternate to SF6 (Credit: CIRED - 24th International Conference & Exhibition on Electricity Distribution)

Following factors have supported the transition from SF6 to g^3 (Credit: GE Grid Solutions, g^3 Technology):

1. Easy retro filling options with support from leading industrial gas suppliers

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2. Device interoperability for diagnostic of $g^{3.}$
3. Easy end of life management
4. g^3 gas is applicable to all voltage levels ranging from MV to EHV
5. g^3 gas is usable for similar ambient temperature ranges as that of SF6.
6. g^3 gas is nontoxic and categorized in the equivalent safety class as SF6.

Comparing g^3's global warming potential(GWP), GWP reduces by 98% when evaluated against SF6. When filled in the GIS, the GWP of the gas is further reduced by more than 99% as required gas mass of g^3 for one bay is approximate half that required quantity for SF6. The g^3-GIS has 15% increased impact on ozone depletion on account of greater use of polytetrafluoroethylene (PTFE) substance in the circuit breaker to align with properties of the substitute gas. As PTFE quantities are miniscule, this rise is marginal (only 2.8 g of CFC-11 equivalent weight over the life cycle).

Fig 1.5 Use case of g3: Europe(Credit: g3: The SF-free solution in practice White paper, GE Grid Solution)

B. Rooftop solar PV for customers

Solar rooftop PV system has solar panels mounted on residential or commercial spaces. They provide an option of distributed generation thereby not only reducing the customer dependency on electricity utility but also provide revenue earning opportunities to customer, housing societies and commercial complexes. Depending on tariff option and state wise provisions, solar units more than threshold are banked and purchased by utility at the end of year as per regulatory directions. Housing societies have handsome opportunities through rooftop solar PV installation to utilize their idle space and reduce monthly electricity overheads. As per MCAP(Mumbai Climate Action Plan), Mumbai has solar potential of 1724 MW through rooftop solar plants. This can help meet half of the city's demand during summer[9]. Case study of one of the housing societies is explained.

Case Study – One of the Housing societies in Kandivali West installed three nos. Rooftop Solar plants(Total 20.52 kW) on terrace as per the common connection connected load. Half cut mono PERC solar cells panels were used with 535 W 24 V capacity. Half-Cut cell mono PERC solar module's solar cells are cut in half due to which its performance and efficiency enhances. Enhanced performance is exhibited through less resistive losses and more power output. Smaller cells are also durable as they are subjected to less mechanical stress and reduced possibility of cracking due installation and operation. Half cut cell also has high shade tolerance as they are connected in parallel and under performance of single cell does not affect the overall module efficiency.

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Reading of solar meters were recorded for period of 7 days and vis a vis generation potential is calculated. Based on it, the payback period for 20.33 kW plant is calculated. GHI(Global Horizontal Irradiation) potential for Mumbai is 5.4-5.6 kWH/Sq m/day[11]. Day light hours vary in Mumbai from 12:07 Hrs in Mar, 13:17 Hrs in June, 12:08 Hrs in September and 10:59 hrs in December. Clear sunny days are approximately 250 days. Total Area of solar panel is 82.69 Sq m. Considering the GHI, daily solar irradiation is 447 kWH. Efficiency of solar cell is 21%. **Solar generation envisaged/day is 93.7 kWH.**

PV nstalled Capacity (kW)	KWH (Generated) measured through Solar Meter						
	6/01/2023	7/01/2023	8/01/2023	9/01/2023	0/01/2023	1/01/2023	2/01/2023
3.56 KW	4	3	4	4	4	4	3
3.56 kW	5	4	5	5	5	5	2
3.21 kW	2	1	2	2	2	2	1
Total kWH	1	8	1	1	1	1	6
Daylight hrs[10]	1:07:15	1:07:51	1:08:28	1:09:06	1:09:45	1:10:25	1:11:06

Table 1 : Solar PV Rooftop Plant 20.33 kW data (Housing Society, Kandivali West)

Summary – Mumbai has the potential to generate 4.6 solar units per kW. Rate per kW of 535W Mono cut solar panel including material, installation and liasioning is INR 58,642/. Average unit cost of electricity is considered as INR 8.5/unit. Simple payback period calculated is 5.6 Years. Carbon footprint reduction achieved through 20.33 kW Solar rooftop PV plant in Mumbai is 21.12 Mtoe/Year[12].

C. Use of Bio-degradable Ester Oils in Transformers

Mineral Oils which are byproduct of petroleum have been the obvious choice of most of the electrical utilities for transformer insulating and cooling media in view of standard performance, no strict regulation for use and disposal, relaxed fire safety norms and low cost. As an estimate global Transformer oil market is set to grow at CAGR of more than 8% surpassing 30 billion $ in 2027. Mineral oil contributes 65% of the total market share. Mineral oil being petroleum based product is plagued by factors like low flash and fire point and are not recommended to be installed in basement and stilt of building as per CEA regulations. Further disposal of mineral oil is done only through authorized agencies in view of non-biodegradability and toxic nature. Natural ester (vegetable oils) are innovative alternative to mineral oil and offer multiple advantages beside providing a fire safety(Natural Ester are k-Class liquids with fire point > 300 Deg C). Comparison of mineral and natural ester oil is as per attached shown table:

Parameter	ASTM Test Method	Mineral Oil (Applicable Std.)ASTM D3487	Natural Ester (Applicable Std.) ASTM D6871
BDV (kV) 2mm gap	D1816	≥ 35	≥ 35
Water/Moisture Content (mg/kg)	D1533	≤ 35	≤ 200
Acid number/Acidity (mg KOH/g)	D974	≤ 0.03	≤ 0.6
Flash point (°C)	D92	≥ 145	≥ 275
Fire point (°C)	D92	-	≥ 300
Viscosity (cSt) 100°C	D445	≤ 3.0	≤ 15
Viscosity (cSt) 40°C	D445	≤ 12.0	≤ 50
Biodegradability[13]		Non-biodegradable	100%

Table 2 :Comparison of Properties Mineral Oil & Natural Ester Oil

Natural Ester oil filled transformers offers following advantages over Mineral oil filled transformers:

1. Readily bio-degradable and nontoxic. Emits less GHG compared to mineral oil.
2. Enhance life of transformer insulation – Insulation class with NE oil is upgraded due to higher thermal conductivity as IEEE C57.154. Due to it, transformer can be overloaded up to 110% on a continuous basis. Alternately for similar rating, transformer size can be reduced up to 10%.
3. High resistance to moisture due to transesterification process.

Apart from procuring the new transformer procured with Natural Ester oil as dielectric insulating fluid, electrical utilities have the option to convert the currently mineral oil filled transformer to natural ester filled transformer through retro filling. In retro filling process, existing breathing transformer is converted to sealed type transformer by installing NRV(Non return valve) or COPS(Conservator Oil preservation system) and filled with NE oil post flushing the mineral oil through transformer winding. Leading utilities like Adani Electricity and Tata power have retro filled distribution transformers satisfactorily.

Summary – In view of multiple benefits, Natural ester oil provides an edge over mineral oil filled transformers. Calculation of LCC(Life cycle cost) indicates that though capital cost being on higher side, LCC is comparable for both options. Fire safety and biodegradability are added features which utilities need to capitalize.

IV. CONCLUSION

Indian Electricity sector is getting ramped up and keeping pace with global players in terms of capex infusion, use of digital technologies and setting up a frame work for sustainability. There is huge potential for Indian utilities to adopt new technologies like use of methanol blended petrol for operations, integrating the solar, wind and battery storage systems to create a micro grid, self-healing grids to reduce the environmental impacts due to contingency power purchases. Besides use of sensorization and AI in

applications related to maintenance and monitoring shall ensure reliability centered maintenance of assets which shall fortify the ESG compliance of electrical utilities.

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