in India. Uses of smart grids, advanced metering infrastructure, automation, drones, and remote sensing are possible ways of improving the reliability and mitigating the risks of various natural hazards to the electricity infrastructure (Nicolas, *et al*. 2019).

Conclusion

It can be said that in the current state the power sector, especially the electricity infrastructure and services, lacks the 4R's of infrastructure resiliency. A coordinated approach for mainstreaming risk assessment and evidence-based research of performance gaps from the past hazards will help in creating a roadmap for the future. We are hopeful that Coalition for Disaster Resilient Infrastructure will be a game changer for India. EF

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DISASTER MANAGEMENT IN HYDROELECTRIC POWER PROJECTS

Power sector is vital because economic growth of a nation depends on it. The hydropower projects face both natural disasters such as floods, earthquakes, and cyclones and man-made disasters such as bomb explosion, fires, and terrorist attacks. Such disasters result in extensive damage to infrastructure and cause loss of lives and disruption of electric supply. In this article, **Shambhu Ratan Awasthi** and **Deepak Joshi** discuss disaster management in power sector.

Normally projects are planned and designed taking into consideration the latest design norms that are framed with lessons drawn from past disasters. A disaster management plan helps to deal with such disasters promptly without any confusion on role and responsibility.

Power sector is vital for any country because economic growth of a nation depends on it. The hydropower projects have to face natural disasters such as floods, earthquakes, and cyclones. In addition, they are subjected to man-made disasters such as bomb explosions, fires, and terrorist attacks. Such disasters generally result in extensive damage to the infrastructure and cause loss of lives and disruption of electric supply, which in some cases may be for a long period of one year or even more.

Disaster is defined as an unwarranted, untoward, and emergent situation that results in heavy toll of life and property and is a calamity sometimes caused by 'force majeure' and also by human error. Identification of all types of disaster involves a critical review of the ground reality and study of past disasters in similar situations. In India, the Disaster Management Act, 2005 lays down institutional, legal, finance, and coordination mechanism at various levels, namely, national, state, district, and local.

Disaster Management

A proactive approach is necessary to avoid/minimize any disaster. The Central Electricity Authority has issued a Disaster Management Plan (DMP), 'generic document for developing crisis and disaster management plan for hydropower stations', for hydroelectric power projects. DMP aims at minimizing the damage and restoring of the normal life at the earliest.

It is felt that in order to avoid/minimize the probability of disasters in power houses, possibilities of the following may be explored:

- Bulk oil devices (e.g., OPU) may be separated from main machine by a strong partition wall.
- In underground power plants, diesel/petrol vehicles may be replaced by battery-operated vehicles.
- There should be a review of existing hydel power stations (surface/semi-underground power plants) for provision of emergency exit at the other end of main entrance. In existing hydel projects, emergency exit is rarely provided as the other end is near a river bank.
- Installation of batteries for emergency lighting should be above the maximum flood level so that emergency lighting supply is not disrupted during longer periods of disaster.
- There should be provision for fireproof clothing for power plant personnel so that they can escape in case of fire disaster depending on its severity.
- Fibre boats may also be kept for evacuation of power plant personnel during a flood disaster. The 'dos or don'ts' instructions to be followed during disaster may be depicted on daily approach route, working place, all floors, control room, and so on. Its awareness among workers of power stations may be checked periodically.
- Wireless walkie-talkie as an alternate communication system may be provided.

Existing Hydel Power Projects: Review of Some Disasters

The layout and specifications of hydropower projects depend mainly on the water resource and location of the site. These parameters differ from site to site and are never identical. They are categorized as tailor-made, that is, each project is unique. There are two major elements of the project, namely, storage dam and power plant. The projects that have large dams to create storage reservoirs are more susceptible to the dam failure mainly due to flooding and earthquake.

Dams

Large concrete dams are designed to withstand a range of static, hydrological (or flood) and earthquake loadings. The failure of concrete dams is caused by one, or a combination, of the following reasons[1]:

- Overturning under the pressures of water, silt or ice, including uplift pressures
- Overtopping from severe flood or from reservoir slope failures, leading to structural failure, spillway failure, or excessive scour
- Downstream sliding on pre-existing weak planes
- Abutment instability
- Foundation seepage or erosion
- Concrete cracking and fracture due to overstressing
- Seismically-induced stresses and displacements in the concrete and the foundation

Case Study I: Machchhu Dam Disaster Caused by Abnormal Floods

The spillway of the dam is designed on the basis of estimated Probable Maximum Flood (PMF). It is a case of disaster caused by the underassessment of PMF.

The Machchhu-II dam on River Machchhu was completed in 1972 in Morbi district, Gujarat. It is an irrigation scheme with the storage capacity of 1.1×10^8 m^3. The dam had masonry spillway in river section and earthen embankments on both sides. The dam is 22.56 m high above the river bed and has a crest length of 164.5 m overflow section. This earthen dam has a total crest length of 3742 m. The failure was caused by excessive rain and massive flooding occurred on August 11, 1979 resulting in the disintegration of the earthen walls of the Machchhu-II dam. The spillway was designed for a flow of

5663 m^3/s of water on the basis of PMF of 5409 m^3/s. The actual flow following the intense rainfall reached 16,307 m^3/s. The water walls of 3.7–9.1 m height inundated within 29 min the low-lying areas of Morbi industrial town located 5 km downstream of the dam. Thousands of people died in this disaster.

After disaster, hydrology was reviewed and PMF was modified to 21,000 m^3/s. However, before the reconstruction of the dam, a still larger flood occurred and PMF was further increased to 26,400 m^3/s, which is much higher than the original estimate on the basis of which dam was designed just two decades ago.

Case Study II: Investigations in the Koyna Mega Earthquake[2]

An earthquake of magnitude 6.3 on Richter scale struck Koyna on December 10, 1967 where a large dam was built in 1962. It shattered the belief that being the solid rocks Deccan Traps were not prone to earthquakes.

By continuously monitoring the activity around the reservoir, it should be possible to predict an earthquake ahead of its occurrence. In the region, no earthquake was reported on the artificial Shivsagar lake before the construction of 300 ft high and 800 ft wide dam. Seismologists argue that large reservoirs hold huge quantity of water that can crack and fissure inside the earth. This can weaken the surrounding rock mass and trigger earthquakes. Many earth scientists believe that Koyna is a case of reservoir-induced earthquake. However, final outcome of the study is awaited.

Power Plants

Sometimes, the faults or failure of some power plant equipment or systems may finally result in disaster. In hydropower plants, runaway speed condition along with the failure of the governing system to send command to stop the incoming water to turbine may lead to extensive damages. Such a situation may arise due to the failure of DC supply system in power plants, which impairs protection, controls, emergency lighting, and so on.

Case Study III: Bhandardara-I Power Plant in Maharashtra

The 1 × 10 MW, 11 kV, 375 rpm Bhandardara-I Hydro Power Project in Ahmednagar district in Maharashtra is such a case. The power plant is located at the foot of Bhandardara Dam (82.35 m high and 737 m long), which was built across the Pravara River in the 1920s.

1 Brown, E. T. 2017. Reducing risks in the investigation, design and construction of large concrete dams. *Journal of Rock Mechanics and Geotechnical Engineering*, **9**(2): 197–209

2 Somasekhar, M. 2018. 50 years after Koyna, lessons from the mega earthquake. *BusinessLine*. Details available at https://www.thehindubusinessline.com/news/50-years-after-koyna-lessons-from-the-mega-earthquake/article9988376.ece, last accessed on 6 November 2020

This power plant with a head of 69 m commissioned in 1986 was equipped with Francis turbine and owned by the Water Resource Department of Government of Maharashtra. Its generator had semi-umbrella type of bearing arrangement with thrust and a guide bearing below the rotor and a guide bearing above the rotor.

The incident occurred in 1994 when the generating unit speeded up to runaway speed. At the same time the failure of DC power supply impaired the backup controls and protection systems. The unit continued to operate at runaway speed because governor failed to transmit the signals to close the intake gate and main inlet valve. The generator was severely damaged. Its shaft got bent and a part of the rotor rim along with two poles flew away damaging the stator. The part of the rim broke the generator barrel and was thrown out to the intermediate generator floor. The powerhouse was flooded with water and remained so even after several days. The damages were so extensive that the power plant was rendered non-operational.

The generating unit with higher capacity of 12 MW was bid in 1996 on build, own, operate, and transfer (BOOT) basis for rehabilitation of the damaged power plant. The new turbine is rated 12.564 MW, 428 rpm with a rated head of 69 m and discharge of 23.69 m^3/s. The 11 kV generator, governor, bus duct, main inlet valve, control room equipment, 11/132 kV transformer, and so on were replaced except draft tube, DT gate, spiral casing, and EOT crane. Civil work was confined to the damaged generator barrel and flooring. The project was commissioned in July 2001. It became the first successful privatized project in hydropower industry in the state of Maharashtra.

Conclusion

The importance of the disaster management was realized and action was initiated in early 21st century. Prior to that project, planning was based on past information of similar projects and lesser consideration was given to feedback from disasters. It is therefore felt that inspection of existing hydel power stations from disaster point of view is the need of present time.

It is high time to share globally the information on disasters of all types in detail in order to reduce the risks and damages due to disaster. In fact, time has come to initiate a dedicated channel to share information on disasters globally.

It is felt that teams of experts for handling of disasters of power sector may be formed in the country. The teams may visit all powerhouses and large substations and suggest measures to handle disaster in respective powerhouses and substations. The teams may also help to form exclusive team of working personnel of powerhouses to handle disaster and monitor periodically safety measures required to reduce damages if disaster occurs. EF

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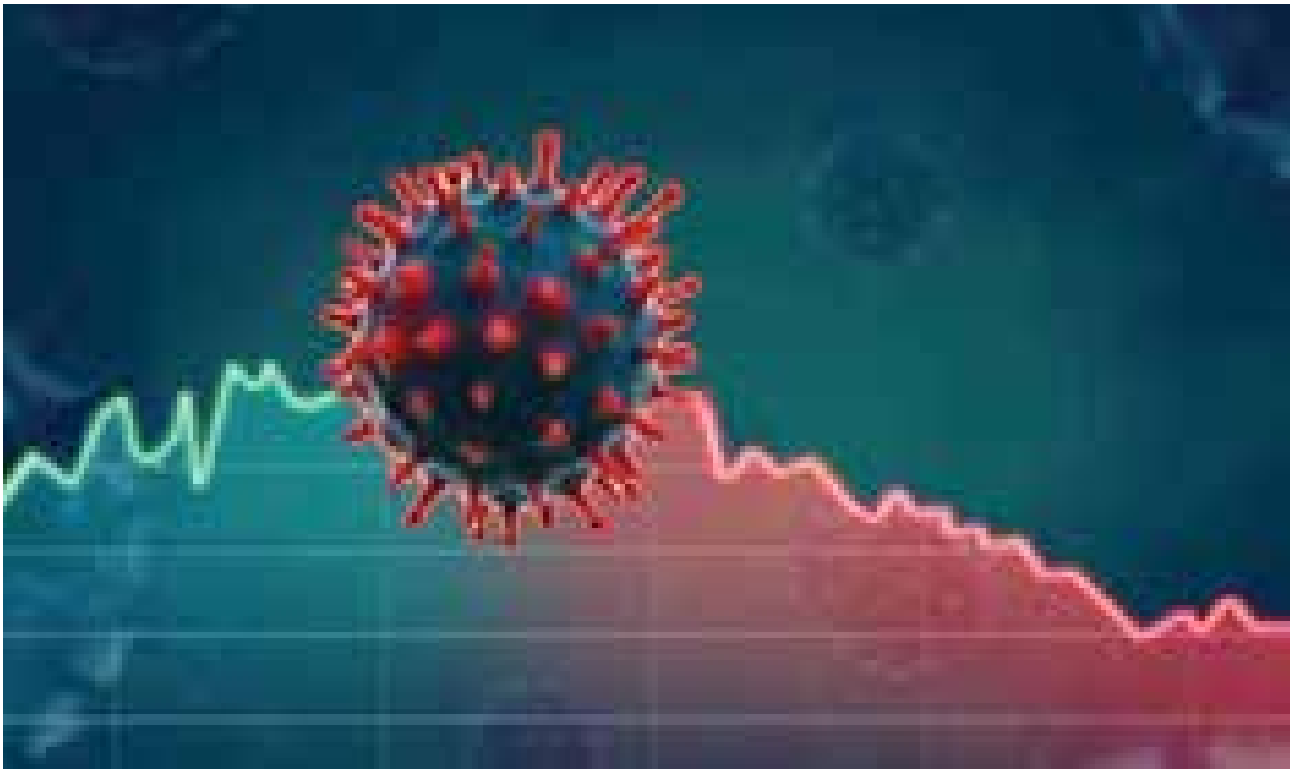
Impact of Coronavirus on Solar Sector in India

COVID-19 is having an especially negative impact on the renewables sector. One of the main problems relates to the delivery of equipment to power plants. Owing to the outbreak at a global level, the impact on the society as well as the economy is very high. In this article, **Diksha Gairola** discusses the impact of COVID-19 on India's solar sector.

According to WHO's report on March 15, 2020, there were 153,517 confirmed cases of coronavirus disease (COVID-19), and the total number of deaths globally was 5735. China had 81,048 confirmed cases and 3204 deaths. The WHO risk assessment marked the risk due to this global outbreak as very high. Almost 80% of the manufacturing was done by China for every other country.

Now, the coronavirus has affected more than 50 million people around the globe and many efforts have been undertaken by countries to stamp out the pneumonia-like illness. There have been lockdowns, mass layoffs, widespread halts of international travels, and battered financial markets. The recent attempts to revive social life and financial activities have resulted in another surge in cases and hospitalizations.

Because of the deteriorating health of citizens as well as health workers, governments across the globe have been forced to limit public movement and close businesses and venues in a bid to slow down the spread of the virus. This has had a catastrophic impact on the global economy.



The "worst is yet to come" given a lack of global solidarity, Tedros Adhanom Ghebreyesus, head of the World Health Organization, said at a briefing in Geneva on June 29.

"We need to sacrifice a little now to get back to what we used to be able to do in the future," said Dr Ken Lyn-Kew, a critical care pulmonologist at National Jewish Health, a hospital in Denver. "If we don't, a lot of our loved ones aren't going to be there when we get back together again."

"It is unavoidable that the novel coronavirus epidemic will have a considerable impact on the economy and society," China's President Xi Jinping said, in a televised address, on February 23, 2020.

"The spread of the new coronavirus is a public health crisis that could pose a serious risk to the macro economy through the halt in production activities, interruptions of people's movement, and cut-off of supply chains," Japanese Finance Minister Taro Aso said.

"Honda Motor Co. will reduce vehicle output at two of its domestic plants in Saitama Prefecture for a week or so in March due to concerns about parts supply from China where a new coronavirus outbreak continues to disrupt economic activities," Honda spokesperson stated on March 3, 2020.

All sectors have been impacted as COVID-19 cases keep on rising. The education system is one of the most impacted genres of industries around the world owing to the closure of schools, universities, and colleges worldwide.

A lot of non-agricultural workers were left with no livelihood during the lockdown. Seeing the spike in the COVID-19 cases, total lockdown was enforced at several places.

Coincidently, the crisis came when country's GDP was already rolling off the hill and the gross domestic product growth was at sub-5% per annum. The lockdown in the country where more than half of its population survive on daily wages is further slowing down the economy.

In May, the WHO emphasized the need for a plan that includes testing for the virus and its antibodies, effective contact tracing and isolation, and community education. Antibody tests on the market that could potentially indicate a person's immunity have been unreliable so far. Researchers and drug makers are racing to develop treatments that could hold the key to recovery.

Vaccines are also in development, though the study of one leading candidate from the University of Oxford and AstraZeneca PLC is on hold in the United States while regulators investigate a potential safety issue.

Current Situation

This pandemic has damaged the world's economies by four times compared to the 2009 global financial crisis, according to the Organization for Economic Cooperation and Development (OECD). The energy sector has already felt the impact of COVID-19.

The outbreak has contributed to a dampened demand for oil, resulting in plummeting prices and declining production, especially in the wake of the Russia–OPEC price war. According to

the IEA Oil Market Report – April 2020, global oil demand is expected to fall by a record 9.3 mb/d year on year in 2020. Demand in April was estimated to be 29 mb/d lower than a year ago, down to a level last seen in 1995. COVID-19 has also accelerated the continued drop of gas prices. There has been impact of the reduced demand on utility companies' cash flows and the spillover effect this has on the energy sector.

COVID-19 is having an especially negative impact on the renewables sector. One of the main problems relates to the delivery of equipment to power plants. Owing to the outbreak at a global level, the impact on the society as well as the economy is very high. China is the largest manufacturer and exporter of raw materials globally, and so industries are worried about the outcome in the upcoming months.

India has committed to increase the share of installed capacity of electric power from non-fossil-fuel sources to 40% by 2030. Solar energy is one of the main sources to accomplish the target of 40% of electric power from non-fossil fuels.

India has become one of the top renewable energy producers globally, with ambitious capacity expansion plans to achieve 175 GW by 2022 and 500 GW by 2030, as part of its climate commitments.

India added 1247 MW thermal solar water heating collectors in 2018, taking the total installations to 8.9 GW thermal and ranking third after China and Turkey

for new solar water heater installations. But now the growth has been ceased by a large margin.

India is dependent on China in segments such as electronics, pharmaceuticals, chemicals, and renewables (including especially solar and wind). So, if there is delay by the manufacturing units in China, this will ultimately create a gap in the solar industries in India. The challenges such as land acquisition, grid unavailability, supply chain bottlenecks, and lack of project financing due to the COVID-19 outbreak are making it difficult to achieve any previously set targets by the government.

"Solar prices are expected to rise with the cost of PV modules increasing, as a result of the virus outbreak. This is due to a shortage in module glass and wafers needed to create these systems," the country's largest industry body Confederation of Indian Industry (CII) told Finance Minister Nirmala Sitharaman and External Affairs Minister S Jaishankar in a presentation.

The PV module itself costs 60% of the installation cost of a solar plant and beating all the competitive prices, China manufactures 80% of the solar PV modules. This is ultimately causing delay in the target dates given to the installers and the upcoming future bids for the same. The order for PV module placed during June–July 2019 was supposed to be delivered by January 2020.

The production has been delayed for both wind turbines and PV modules. This situation will be faced throughout the year, as the production delays the whole supply chain and order fulfillment. This gap will eventually result in increased cost of solar and other industries globally.

Owing to this outbreak, Chinese manufactures have informed developers in India about the delay in the production, quality check, and transportation in China and other places. As a result of this, the developers are facing shortage for the raw material that is usually required for solar panels and their installation.

The slight increase in prices due to delayed shipments has added to the 'stress' margin of EPC (engineering, procurement, and construction) players that are at the end of the value chain. All the variable factors across the value chain from the procurement of the bills of material of the panels to the manufacturing and the supply chain are borne by EPC players. They have to bear the brunt of the increasing prices as contracts have already been signed with their end customers.

The operations of public transport, especially trains and buses, have been disrupted. This will create a labour crunch as the current situation of the labour force is in a state of disarray. However, it is a great opportunity for grassroots level workers to enhance the indigenous work and fulfil the supply

chain gap as larger scale industries would not be able to work so efficiently in the upcoming months.

Conclusion

Recently, India has achieved fifth global position in solar power deployment by surpassing Italy. Solar power capacity in India has increased by more than 11 times in the past 5 years from 2.6 GW in March 2014 to 30 GW in July 2019.

In this outbreak of coronavirus, India shows the disability to fulfil the demand and supply gap in the market. This negative impact of demand can slow down world's economy because of China and eventually will hit India in no time. As an indirect impact on the economy, this could lead to cut down in budget of companies, ultimately resulting in the fall of demand.

The Government of India is also trying to take steps to support the sector. The MNRE has assured relief by notifying that a time extension of the lockdown period plus 30 days can be provided for all renewable energy projects under the force majeure clause. In another government reprieve, in April 2020, the Central Electricity Regulatory Commission (CERC) passed an order extending the validity of renewable energy certificates (RECs) to October 31, 2020 to avoid demand and supply imbalances in the REC market.

The industries are also hopeful that the government will begin promoting alternatives to the solar cells such as thin-film and other technologies, which are not dependent on China. Also, the government should focus on battery cells developed in India, while promoting the NMC technology from branded manufacturers.

But being optimistic, crisis such as COVID-19 outbreak creates new opportunities in every sector. This could also be a great initiative for government's Make in India plan, especially in analysing India's disability in the field of renewables. Major boosters can be given to set up infrastructure at the domestic or local level.

This will eventually lead to reduction in the supply chain gap in the demand and production of the product and also decrease the overall price of the produce, including manufacturing cost, production cost, and transportation cost (highest of all). EF

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Scaling up Rooftop Solar Potential in Residential Sector by Encouraging Local Authorities

MNRE is focusing on upcoming buildings/new construction so that these have rooftop solar installation as a mandatory requirement. Urban local bodies play a critical role in boosting the rooftop solar in new construction in their area by implementing Model Building Bye-laws. To enable RTS development from planning stage, Ministry of Urban Development has recently included RTS plants for major building projects in all the sectors. In this article, **Neelagiri Emmanuel** talks about rooftop solar potential in the residential sector.

Rooftop Solar Scenario in India

MNRE has set an ambitious target of 100 GW solar energy, which includes 40 GW to be achieved through grid connected RTS (rooftop solar) across residential and institutional sectors. National policies to promote both energy efficiency and renewable energy across residential buildings in India have seen significant progress in the last decade.

To achieve 40 GW RTS, it is necessary that the capacity should increase 32-fold in the next 5 years. The total installed rooftop solar capacity was 1.25 GW till December 2016, and the industrial sector accounted for the largest share, followed by the commercial and residential sectors. A significant part of the remaining target is also expected to come from the industrial sector (44%). The sector has to raise its capacity by close to 37 times to meet this target. The commercial sector also has to increase its contribution by about 37 times to host its expected capacity of 12.06 GW. The expected share of residential and public buildings in the national target is comparatively less, and they also have to increase their contribution by 21 times to meet the national targets. The sectoral growth estimates are calculated based on the assumption that governmental and residential buildings will contribute approximately 10 GW to rooftop solar by 2022.

Residential Buildings Potential for Adopting RTS

Buildings and construction sector is one of the largest sources of carbon emissions, and residential buildings alone account for 22% of global energy use and 17% of energy-related carbon dioxide emissions. Cities cannot take serious action on climate without prioritizing residential buildings. The combination of energy efficiency (EE) measures and onsite or offsite renewable energy (RE) is a powerful tool for tackling building-related emissions.

The residential building stock in India is projected to reach 28.4 billion m^2 by 2037 from 15.3 billion m^2 in 2017.[1] Spurred by increased urbanization, a rise in incomes and standard of living, and increased access to electricity, residential building stock is set to crest to almost double in two decades. This increase will most certainly have critical consequences for India's energy security and its control on emissions, especially if new buildings do not accelerate the pace of integration of EE and RE generation.

Demand for Sustainable Residential Neighbourhoods

From a niche practice restricted to a few industries, work from home will become a norm across most businesses in the post-COVID world. That might show adverse effects on office spaces, which can then be used for mixed use purposes. India is different from other countries like the US where nearly a quarter of knowledge workers have the option of work from home. Considering

1 Details available at https://www.aeee.in/wp-content/uploads/2018/09/Building-Stock-Modeling-Revised-pager.pdf

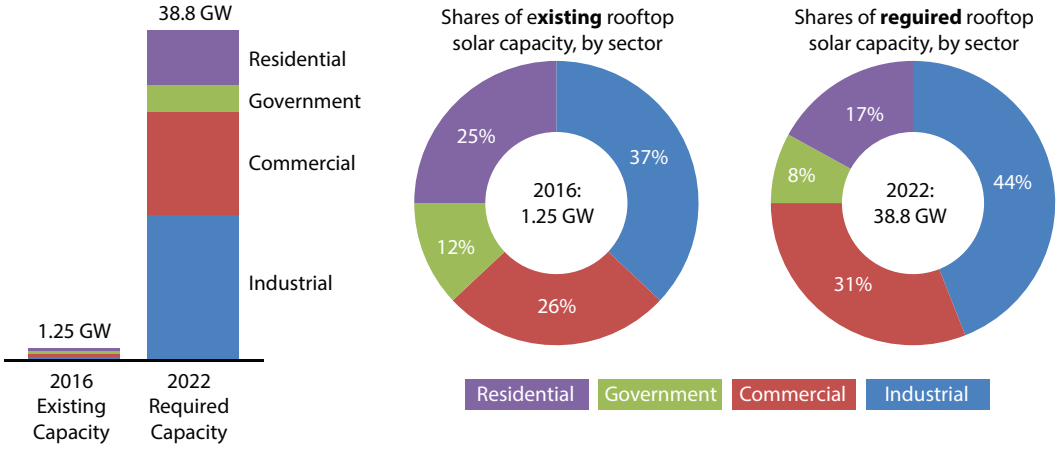

Figure 1: Rooftop solar capacity scenario in 2016 and expectations in 2022

Source: BTI (2017); NITI Aayog (2015); Trivedi, Ray, and Vulturius (2018)

social distancing in post-COVID world, many companies might enhance work from home options. Considering the thoughts, residential spaces have to take a new turn in terms of energy use and sustainable parameters need to drive the future of neighbourhoods.

Solar City Master Plan Programme by MNRE, 2015

Solar City programme developed by the MNRE in 2015 aimed at minimum 10% reduction in projected demand of conventional energy at the end of 5 years at the city level by enhancing supply from renewable energy sources in the city and adopting energy efficiency measures. It is designed to encourage urban local bodies (ULBs) to prepare a roadmap to guide their cities in becoming 'renewable energy cities' or 'solar cities'. However, cities such as Surat and Delhi largely depend on the residential sector for achieving their rooftop solar targets; New Delhi has set a target of up to 7.2 MW of rooftop solar capacity under Solar City Programme, of which 2.1 MW has been installed atop governmental buildings, thus already meeting the rooftop solar target of 1.5 MW set under public sector. The outstanding solar rooftop target according to New Delhi's plan is 5.7 MW.

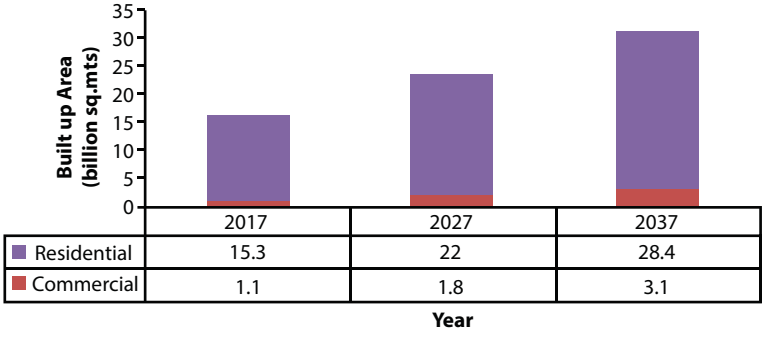

Figure 2: Building stock growth in India

Source: AEEE (2018)

Role of Local Authorities to Scale up RTS in Residential Buildings

Authorities such as CREDAI (Confederation of Real Estate Developers' Associations of India) and RWAs can be crucial to aggregate demand for rooftop solar across the residential neighbourhoods within

cities. CREDAI was established in 1999 with a mandate to pursue the cause of housing and habitat providers. It has grown its membership base since then and has more than 20,000 members today spread across 21 state and 220 city chapters.

To bring a synergy to the sustainability initiatives, CREDAI has launched CSR FOUNDATION, under which it embraces a social and development agenda as part of its wider national engagement with its stakeholders. CREDAI has successfully implemented green initiatives such as "CREDAI clean city movement methodology at Kochi". CREDAI supports developments of new residential buildings with a varied range every year; there are many developments that are partially still under control. CREDAI can be the node to connect the dots between ULBs and RWAs and so on to promote installing rooftop solar in residential buildings with its wide reach and registered members across all major cities in India.

Incentives by the Government of India

The Cabinet accorded its approval for Grid Connected Rooftop Solar Programme Phase II with two components: Component A for setting up of 4000 MW of grid connected rooftop plants in residential sector with central financial assistance (CFA) and Component B for Incentives to DISCOMS based on achievement for installing additional grid connected rooftop capacity in all sectors over and above the base level, with the incentives being limited to the first additional 18,000 MW of rooftop capacity added in the country.

Phase II of the grid connected rooftop solar programme was approved with a target for achieving cumulative capacity of 40,000 MW from RTS projects by the year 2022. The programme will be implemented with the total central financial support of ₹11,814 crore. In the Phase II Programme, CFA for the residential sector has been restructured with availability of 40% CFA for RTS systems up to 3 kW capacity and 20% for RTS system capacity beyond 3 kW and up to 10 kW. For group housing societies/residential welfare associations (GHS/RAW), CFA will be limited to 20% for RTS plants for supply of power to common facilities; however, the capacity for CFA for GHS/RAW will be limited to 10 kW per house with the maximum total capacity up to 500 kWp, inclusive of RTS put in individual houses in the GHS/RWA. Central financial support will not be available for other categories,

that is, institutional, educational, social, government, commercial, industrial, and so on. Under Phase II Programme, focus is on increased involvement of DISCOMs. Performance-based incentives will be provided to DISCOMs based on RTS capacity achieved in a financial year.

Solar Municipal Bonds: the Potential Way Forward

Climate Policy Initiative (CPI) proposed the use of municipal bonds to achieve the goal of about 40 GW of rooftop solar capacity by 2022. It explained how such bonds could be designed and implemented to scale up rooftop solar across the country. The CPI report was produced in collaboration with the Stockholm Environment Institute and the Indian Council for Research on International Economic Relations (ICRIER). As per the findings of the CPI report, it is expected to overcome the three key barriers to the continued growth of the country's rooftop solar sector, namely, high upfront capital expenditures required for installation, perceived performance risk, and limited access to debt capital.

The study proposed a transaction structure in which a special purpose vehicle (SPV) or a corporate municipal entity owned by the municipal corporation would raise green bonds and disburse the proceeds of these bonds through capital lease arrangements to SPVs owned by project developers. This financial transaction structure would be a public–private partnership similar to the design–build–finance–operate model with financing activity handled by a public entity such as municipal corporations or urban local bodies.

Municipal bonds have already been successfully tried in case of other infrastructure projects in India. It is also expected that the solar municipal bond would help reduce costs of rooftop solar power by around 10–14%, which could be a large financial saving. This would allow electricity consumers to adopt solar power by reducing the costs further.

The CPI report findings also states that besides reducing the costs of rooftop solar, municipal bonds can mobilize significant untapped investment from new sources such as domestic institutional investors, which has a potential of US$56 billion in the green bond market and reached a total issuance size of US$156 billion in 2017. For municipal corporations, it will help build organizational capacity to raise municipal bonds for other projects. In case of cities struggling with clean air, this model can help residents save money on electricity, something that helps everyone build clean and sustainable communities.

National Solar Mission Grid Connected Rooftop Solar Programme in India

In order to promote the grid connected RTS systems in the country, cash awards, along with certificates, are being provided under this scheme to all ministries/departments and state/UT governments involved in the implementation. Achievement/

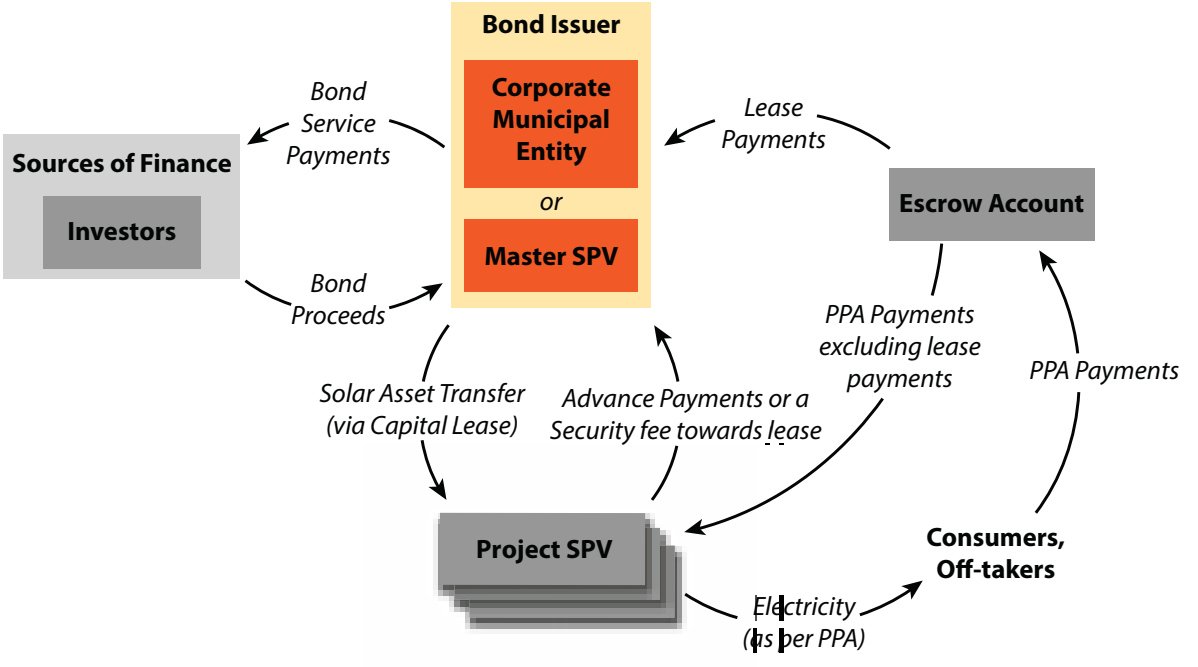

Figure 3: Transaction structure for increasing municipal bond to finance rooftop solar

Source: CPI report on Solar Municipal Bond: Unlocking India's Energy Potential, 2018

installation of grid connected RTS by central/state or local government authorities involves the following:

a. Highest capacity installation by state nodal agencies of renewable energy in states
b. Highest capacity installation by central government departments/ ministries on their buildings
c. Highest capacity installation by state government departments/ ministries on their buildings. Highest capacity installation by government (both central and state) educational institutions on their buildings
d. Highest capacity installation by government (both central and state) hospitals on their buildings. Highest capacity Installation by urban local bodies/local governments
e. Largest capacity installation on a single roof by any of the above organizations

Scheme for Urban Local Bodies

MNRE is focusing on upcoming buildings/ new construction so that these have RTS installation as a mandatory requirement. ULBs play a critical role in boosting the RTS in new construction in their area by implementing Model Building Bye-laws. To enable RTS development from planning stage, the Ministry of Urban Development has recently included RTS plants for major building projects in all the sectors. EF

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MITIGATING THE IMPACT OF DISASTER EVENTS

The Indian power system is unique in terms of geography and topology, and thus it experiences a varying degree of diversity in terms of weather and climate. Power system restoration after a disaster event is a complex process. Preparation before the disaster becomes important. India has come a long way since the 1999 Odisha cyclone and is better prepared to handle natural disasters. **S R Narasimhan**, in conversation with **TCA Avni** for *Energy Future*, talks about disaster management and post-disaster recovery.

Restoring power supply in the immediate aftermath of a crisis is extremely important in mitigating the impact of disaster events. India is particularly vulnerable, given our topographical and geo-climatic complexities. Could you tell us a little about recovering from disaster events in their immediate aftermath?

The Indian power system is unique in terms of geography and topology, and thus it experiences a varying degree of diversity in terms of weather and climate.[1] It faces more than one extreme event commonly known as high-impact, low-frequency (HILF) event. The HILF events in India include cyclones, earthquakes, landslides, localized wind squall, floods, and so on. From 2013 to 2020, India has faced eight major cyclones (Phailin, Hudhud, Vardah, Ockhi, Titli, Fani, Amphan, and Nisarga),[2,3] five devastating floods (including Uttarakhand and Kerala), and three major earthquakes (including 7.7 intensity Nepal earthquake that impacted the border areas). Apart from above, Indian power system faces severe fog in Northern India during winters, severe silt in rivers during monsoon, and thunderstorms during summers. These events impact the power system operation right from generation to utilization of electricity through transmission and distribution. In the post facto analysis of HILF events, it is observed that extra high voltage (EHV) grid survives except for minor damages; however, the distribution system infrastructure (primarily comprising 33 and 11 kV) gets severely impacted. To ensure availability of power under such condition with quicker restoration and adaptation, resiliency aspect becomes important.

Power system restoration after a disaster event is a complex process. Preparations before the disaster like cyclone actually strikes become important. The preparations involve moving equipment (e.g., Emergency Restoration System, tools and tackles, satellite phones, long-range walkie talkies with solar chargers) and skilled workforce to strategic locations nearby for taking up restoration works immediately. The nature of decision-making has to be precise; therefore, pre-event advisories and forecasting play an important role. The

1 Mukhopadhyay, S., S. K. Soonee, S. R. Narasimhan, and R. K. Porwal. 2008. An Indian experience of defense against blackouts and restoration mechanism followed. 2008 IEEE Power and Energy Society General Meeting - Conversion and Delivery of Electrical Energy in the 21st Century

2 Mukhopadhyay, S., S. K. Soonee, V. K. Agarwal, S. R. Narasimhan, and S. C. Saxena. 2014. Impact of super-cyclone Phailin on power system operation - defense mechanism and lesson learned. 2014 IEEE PES General Meeting, National Harbor, MD, USA

3 Soonee, S. K., S. R. Narasimhan, N. Nallarasan, H. K. Rathour, G. Yadav, S. C. Bhan, R. R. Mali. 2015. Impact of very severe cyclone 'HudHud' on power system operation. 2015 Annual IEEE India Conference (INDICON)

control centres release advisories to alert all stakeholders to manage the contingency and take steps to ensure that there is no cascading failure and impact on rest of the power system so that restoration is faster after the disaster. Restoration time is also highly dependent on situational awareness and information sharing; therefore, they are taken care of at control centres. At the control centres too, which are likely to be impacted, staff reinforcements, onsite arrangements, power supply backup, and so on become important along with communication equipment such as satellite phones. Switching off power supplies to the areas likely to be impacted is done in advance to avoid any collateral damage and the system operators have to balance the power system during this period too. In all the disasters which have happened in India, the rest of the power system has remained unaffected and only the area struck by the natural disaster is impacted in terms of power infrastructure outages.

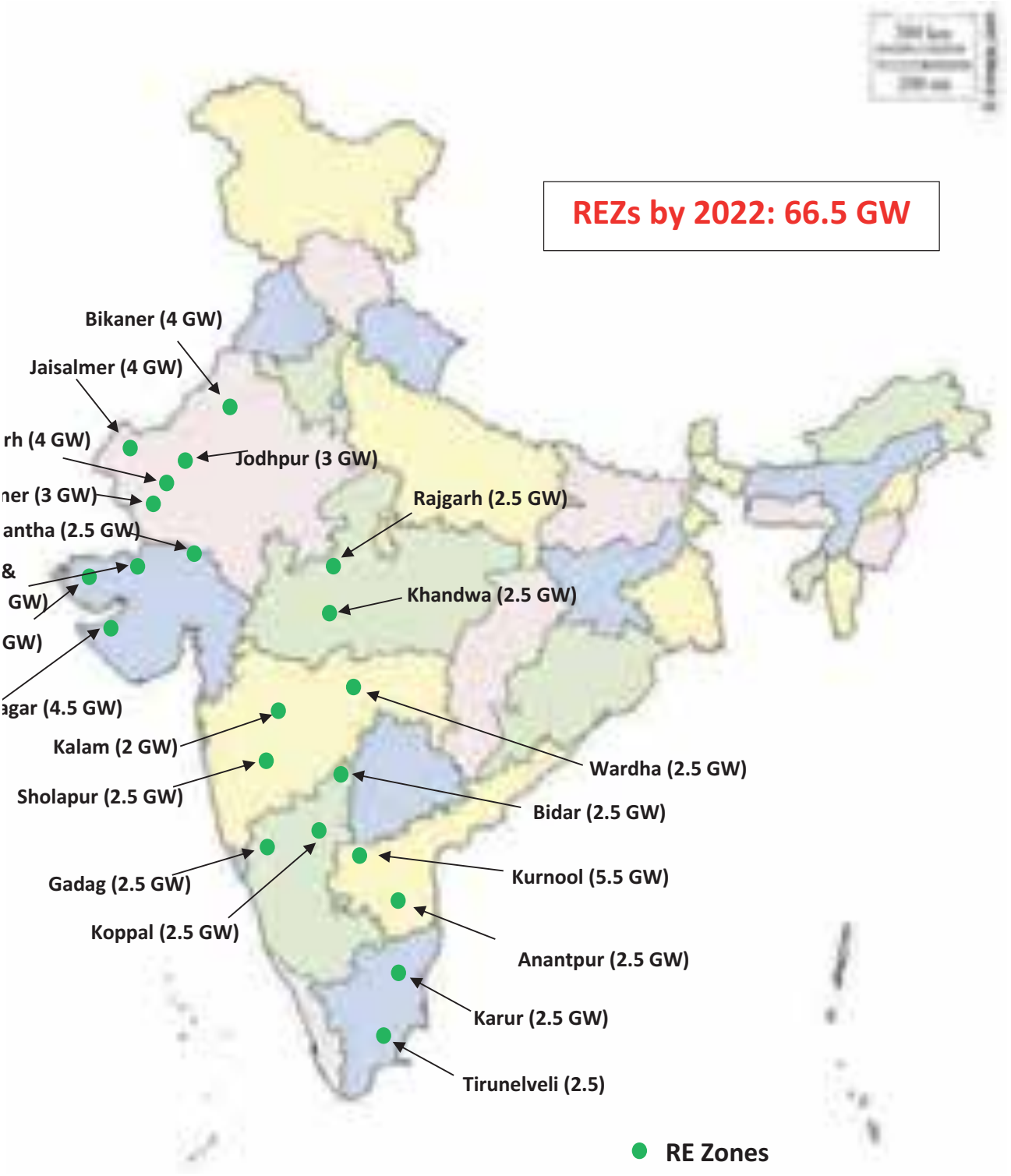
Once the storm or disaster has passed, all the utilities and the state authorities swing into action. The roadblocks due to fallen trees and electricity poles have to be cleared for smooth movement of man and material. Assessment of damage to the electricity infrastructure is done in terms of substations affected, transmission and distribution lines suffering damage, and the workforce and material required. Usually in all such instances, the requirements far exceed that which could be ensured by the locally available utility personnel and reinforcements have to be rushed from the nearby utilities. These reinforcements work under the command of the nodal executive of the affected utility. Food and sanitation arrangements for such workforce are also important. Mobile generators might be required in cases where the restoration of power supply is likely to be delayed. Restoration of voice and data communication links is also a priority area.

For the rest of the power system, contingency plans may be required to be drawn up due to outage of any trunk transmission line traversing through the affected areas or outage of any power station or substation. The control centres often prepare a priority list for restoration of the transmission elements so that the time taken to restore normalcy is reduced.

India has come a long way from the 1999 Odisha cyclone and is better prepared to handle natural disasters.

Could you talk about technologies and innovations which would help with disaster management and post-disaster recovery?

There are various technologies and innovations which are already helping with disaster management and post-disaster recovery. The innovations in satellite-based assessments are enhancing the early preparedness about upcoming disaster events in power system. The periodically updated



information provided by Indian Meteorological Department (IMD) has continuously helped in keeping a track on the path of various cyclones hitting Indian coastline. The time-stamped trajectory with wind speed is helpful in identifying possible impact areas.

High-frequency ocean radar systems used for monitoring tsunami activity and new radar apertures can see through storm clouds. Real-time monitoring system of rain by IMD is helping in planning activities. Information such as wind speed, humidity, and forecasting of track

of cyclones is helping in planning activities. The good communication network, fast broadband, and smartphones facilitate faster flow of communication in case of disaster management. Drones are being effectively used in the sites where it is difficult to get physical access. In the aftermath of any disaster, roads usually get blocked by fallen trees. Damage assessment of transmission towers and substations is done by the aerial drones. Important information such as site images, wind speed, and level of water on selected areas is sent by drones to control centres. All the substations and tower locations are mapped through geographic information system (GIS) nowadays which helps in better planning of the restoration.

The public is impacted by the power outages after such disasters and reduction in the restoration time becomes important. It is here that backup power supplies either through energy storage systems or diesel generating sets become important. As battery storage prices fall, it is possible that residential areas might go for battery energy storage systems (BESS) as a resilience[4] tool to cope with such disasters so that essential supplies can be met before the utility is able to restore supply. From the utility side, there are technologies available to 'harden' the system such as underground cables, gas insulated substations (GIS), mobile substations, which can either ensure that parts of the network remain unaffected or be restored quickly. Grid-forming inverters and distributed generation hold a promising alternative for a black start situation.

4 K. V. S. Baba, S. Mukhopadhyay, S. K. Soonee, S. R. Narasimhan, S. C. Saxena, KVN Pawan Kumar. 2018. Grid resilience in Indian power system. 2018 IEEE 8th Power India International Conference (PIICON)

The implementation of wide area management systems (WAMS) at control centres has helped in providing high-resolution data at control centres. The WAMS-based data help in understanding the impact of disaster on power network. The islanding and overloading are identified timely which help in taking prompt actions. The system restoration schemes are documented by the system operators which is updated as and when system change takes place. The advancement in power system simulation and modelling has helped in assessing the restoration plan. The black start capability of generating plants and associated path is optimized using the simulation tools.

Climate change related extreme events are expected to further increase disaster risk. Climate change is also expected to exacerbate seasonal stresses (higher temperatures, greater water stress, greater flooding, and more extreme storms). Could you talk a little about what would be the impact on power system operation? What could be strategies for adaptation and mitigation?

While natural disasters and their impact have been covered earlier, there are sporadic events which are becoming frequent and a possible impact of the climate change. Intense heat spells are common which cause a sharp increase in the power demand. Such heat spells are usually accompanied by water shortages too and have impacted operation of some coal-based power plants. The summer season in northern parts of country is also prone to high speed localized thunderstorms. This causes sharp reduction in load creating issues in load generation balance. This has the potential to impact reliability of the power system.

During April–June, there are instances of strong local winds creating a torsional impact on transmission towers accompanied by collapse of the towers. The utilities report of changes in the wind zone than what the towers were originally designed for.[5] The utilities are taking measures to further strengthen some of the transmission towers in these vulnerable locations. Similarly, the advanced asset health monitoring tools which give indicators for any anomaly help in assessing the real-time strength of power network.

Siltation is a serious problem for the hydropower projects in the Himalayan region. There are frequent instances when the silt level in the river exceeds 5000 ppm (parts per million) during the monsoon and the hydropower plants have to be taken out of the system till the silt level comes back to normal levels. This has an impact on the reliability of the power system. Monitoring the silt levels further upstream and its telemetry to the control centres has helped in taking advance actions. Protocols for gradual closure of units in such situations have been put into operation.

In the plains, we have frequent instances of heavy rainfall in a short period of time leading to flooding of some of the substations and the need to switch-off some substations as a precautionary measure. Contingency plans have to be formulated at short notice based on the red alerts issued by the IMD for such events. Similarly, there are many instances of local rivers changing their course frequently and impacting the transmission lines passing through that area. In the North Eastern region, lightning strikes frequently impact the transmission network. All these factors are taken into consideration during the operational planning phase.

In the Himalayan region, there are frequent instances of heavy snowfall in a short period of time. This has impacted the transmission network passing through the area and led to islanded

5 CENTRAL ELECTRICITY REGULATORY COMMISSION order in Petition No. 9/SM/2014 on subject "Investigation of tower collapse and load crash in Northern Region on 30.5.2014."

operation of a part of the power system. Alternative transmission corridors built based on the feedback from system operators have minimized the impact of such outages.

With increasing levels of suspended particulate matter, smog conditions during winter have also impacted the transmission system as there are trippings on account of line insulator flashover. In the last decade, there has been an extensive replacement of porcelain insulators with higher creepage distance insulators (polymer, etc.) in several parts of the National Capital Region and the plains of Northern India. However, the spread of pollution is presenting a new challenge and more areas would need to be covered based on the pollution mapping updates. As a remedial measure, insulator pollution mapping is carried out by transmission entities. The pollution level measurement is carried out in the dummy insulator string mounted on the transmission towers. The dummy insulator strings are mounted in the suspension mode in all the considered transmission towers.

With increasing urbanization and reliance on mass rapid transit systems, which are usually underground, failure of power supply for a prolonged period (due to city floods or any natural disaster) can lead to public safety issues. Inter-sectoral coordination (gas, electricity, drinking water, transportation, telecommunication, civil defense, etc.) becomes important and regular mock drills are required to ensure a high level of preparedness.

Does the transition to renewable energy sources and distributed electricity generation have implications for stability of grid operations, especially during disaster events?

Renewable energy (RE) sources, such as wind and solar are intermittent in nature. Their output is much dependent on the external factors such as solar insolation level and wind speeds. RE-based generation is more affected by extreme weather scenarios and disturbances in the transmission system. The RE-based resources need strong AC network for reliable operation; the disturbances in the transmission network due to disaster events may induce mis-operation of power electronic-based controllers in RE generation sources.[6] The August 2019 UK power blackout and September 2016 South Australia blackout are a few examples that highlight the need for further understanding of the behaviour of the power electronic devices at all levels and the need for non-ambiguous technical standards.

The integration of renewable generation requires flexibility and balancing of conventional sources of generation. The system inertia, which opposes the sudden change in frequency, will reduce with increasing penetration of renewable generation as there will be decrease in on-bar synchronous machines in the system. It will lead to sharp frequency changes and a high rate of change of frequency in case of contingencies. Voltage stability issues may arise due to reduction in short circuit current capacity and reactive power control. Large solar parks could also be impacted by cloud cover leading to sharp changes in solar generation (similar to that encountered during a solar eclipse). All these indicate the need to maintain an increasing quantum of generation reserves in the system.

As we understand power electronic devices better, we can harness the capabilities of these devices with respect to voltage control as well as black start. As already mentioned, grid-forming inverters hold promise; however, status in real time is extremely important during restoration to avert any adverse incident. The real-time information about the distributed generation is extremely important during system restoration or else it can be counterproductive also.

Could you talk about future policies and action strategies which you think would be useful?

Resilience needs to be factored in our planning process at all levels. While economies of scale have led to large power stations, solar parks, high capacity transmission corridors, they also introduce additional vulnerabilities in the system. 'Small is beautiful' is an oft-quoted saying and is quite apt in the context of resilience of systems. It is said that 'wires' alone don't bring reliability and resilience. These have to be brought about through a myriad of other aspects, such as protective systems, processes, and coordination involving human beings. As stated earlier, technologies are available, but the real challenge is to incorporate these resilience aspects into the planning process. Increasing electrification of the economy would bring unforeseeable challenges into the future. As more 'unknown unknowns' get converted to 'known unknowns' with learning, policies also need to be flexible enough and keep pace with these developments. EF

Disclaimer: The views reflected in the article are personal and not necessarily that of Power System Operation Corporation Limited (POSOCO).

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6 Jennett, K. I., C. D. Booth, F. Coffele, and A. J. Roscoe. 2015. Investigation of the sympathetic tripping problem in power systems with large penetrations of distributed generation. *IET Generation, Transmission & Distribution*, vol. 9, pp. 379-385

Enhancing Resilience Through Early Warning Systems:

An Approach to Disaster Risk Reduction

The Energy and Resources Institute (TERI), in collaboration with the National Disaster Management Authority (NDMA), organized a webinar on the launch of a flood early warning system (FEWS) on August 13, 2020. The FEWS developed for Guwahati city was launched by Shri G V V Sharma, Member Secretary, NDMA, and Dr Ajay Mathur, Director General, TERI.[1]

The welcome note was delivered by Dr Ajay Mathur. He stated that the issue of flooding and the ability to tackle it has become a major concern as urban planning and regulation could not keep pace with the rapid growth of urban areas and cities. He stressed that flooding has become a menace across the economically important centres of the country, such as Mumbai, Chennai, and Guwahati. Emphasizing on the increase in the trend of climate-related disasters in the future, he said that while the total seasonal rainfall of regions has not changed much, the intensity of rainfall has increased for short durations, resulting in the occurrence of flash floods across cities. Unplanned urbanization and increased climate variability were deemed as the crucial factors that made it important for cities to focus on resilience. It was stressed that as the geography and topography of Guwahati city make it prone to flooding post rainfall, preparedness is a major factor that can enhance resilience of the city. Congratulating the team on the development of the FEWS, he stated that early warning systems such as FEWS could help enhance the resilience of cities and regions that face perennial issues of urban flooding by helping in the development of a flood management roadmap for those regions.

In his keynote address, Shri G V V Sharma, Member Secretary, NDMA, emphasized the importance of early warning systems, mentioning that the expectations of civil society on the disaster management apparatus have been increasing. He noted that if mortality rates, losses, and damages due to disasters could not be arrested and further reduced, the advances in science and technology would be futile. He also stressed on improving the actual application and use of such technology by the designated government functionary tasked with the responsibility of taking up disaster response work. Mentioning that early warning systems are only one aspect of disaster preparedness, he also drew focus towards on the ground implementation of technology and mitigation initiatives, such as proper management and disposal of solid wastes in order to avoid clogged drainage systems, and reiterated the importance of state disaster management plans notably at district levels in order to improve preparedness for disasters. He cited examples of cities such as Cuttack that have developed dewatering pumps to pump out the excess water in situations of urban flooding. He also touched upon issues of information dissemination among citizens and the involvement of the community in the flood early warning system.

Mr Prasoon Singh, Project Lead and Associate Fellow, TERI, gave a presentation that described the working of the FEWS model. The system was developed in collaboration with IMD, NESAC, and TERI-SAS. The system uses the weather forecast of WRF model of IMD. The geographical and topographical information of the city was provided by the North East Space Application Centre (NESAC), the Assam State Disaster Management Authority (ASDMA) provided information relating to disaster events and floods in the city, and information about the drainage system and the river system was provided by the Guwahati Municipal Corporation (GMC). The system is based on weather forecasts from IMD that provided hourly rainfall data for the city. The temporal resolution of the data is 1 hour. Based on the hydrologic model results, it can predict the water level discharge and the flood level across the different regions of the city, while also alerting the authorities if and when the threshold limits are crossed. The results of the same are published on the domain and can be accessed at http://fews.teriin.org. The model uses rainfall time series and the discharge of the same to predict water level at the different sections of the river.

Dr Vinay Sinha, Associate Professor, TERI School of Advanced Studies (SAS), then shared his insights on the FEWS model for Guwahati. He focused on important aspects such as initiation and importance of early warning systems, technology and inter-institutional collaborations and future scope of the same. He also stressed on the need for states to tap into their potential and develop such systems.

The panel discussion that followed was moderated by Mr R R Rashmi, Distinguished Fellow and Programme Director, TERI, and focused on the role of science communication and early warning in disaster risk reduction. Mr Rashmi talked about the increasing intensity of extreme events, the factors affecting vulnerability, and the importance of utilizing risk mapping and advancing technologies, discussing similar projects being undertaken for both pollution and weather forecasting. Mr Pankaj Chakarvarty, ASDMA, gave an overview of how the development of this project will be helpful for Guwahati city and the factors that had led to its necessity. Shri B P Yadav, DGM Hydrology, IMD, talked about the work of the IMD, their efforts at improving forecasting systems, and their initiatives for developing specific flood forecasting and flash flood warning systems for both cities and other flood prone areas (such as the Doppler radar network for the Himalayan regions). While discussing the importance of better forecasting to aid disaster prediction and management at the all India level, he highlighted the

1 Full webinar can be accessed through the link: https://www.teriin.org/event/enhancing-resilience-through-early-warning-systems-approach-disaster-risk-reduction

importance of developing location-specific forecasts.

Shri P L N Raju, Director, North East Space Application Centre (NESAC), focused on what NESAC is contributing for north-eastern India in the form of developmental activities for disaster risk reduction and enhancing resilience. He stressed on the importance of effective communication to inform the affected people and highlighted the process of recognizing and demarcating areas where disasters are expected to happen and linking them to communication strategies to issue alerts.

Continuing the discussion on the initiatives taken by NESAC, Dr Diganta Barman, Scientist F, NESAC, mentioned how the FEWS that has been developed for Guwahati is similar to the FLEWS developed for riverine flooding for Brahmaputra. Commenting on the importance of keeping warning systems as pilot systems for a few years before operationalizing them for public, he gave the example of how storm water drainage system projects need to be calibrated and validated with more events to allow performance to its optimum limit and updated every 2–3 years so that new drainages developed can be taken care of in this model. He also talked about how riverine flood models can be combined with this project to develop it as a full-fledged early warning system.

Professor P K Joshi, Chairperson, Special Centre for Disaster Research (SCDR), Jawaharlal Nehru University (JNU), talked about enhancing resilience through early warning systems. He stressed on the importance of developing similar system for other cities and utilizing other science-based tools and technology to allow informed decision-making for combating disaster risks. He talked about stakeholder collaboration and partnership and the role that can be played by policy makers at regional and national levels. He recommended co-designing of disaster risk reduction (DRR) solutions towards participatory action and communication, stressing that the approach and product development should be open ended to support stakeholders who need it. He also talked about the importance of theoretical, productive, and practical knowledge in disaster risk reduction.

Mr Saurabh Bhardwaj, Area Convener and Fellow, TERI, provided a climate change perspective on building resilience. Highlighting the Indian context on changing climate and regional extremal behaviour of rainfall and warming, he talked about the need to develop FEWS at catchment scale and in urban centres and the work TERI is doing to address this. Discussing the importance of climate and regional modelling, stakeholders' involvement, and local level risk assessments, he highlighted the importance of availability of climate services and tools at regional levels. EF

CURRENT R&D RENEWABLE

Grounded Reality Meets Machine Learning: A Deep-Narrative Analysis Framework for Energy Policy Research

Energy Research & Social Science, Volume 69, November 2020, 101704

Ramit Debnath, Sarah Darby, Ronita Bardhan, Kamiar Mohaddes, and Minna Sunikka-Blank

This paper illustrates the potential of deep-narrative analysis in energy policy research using text analysis tools from the cutting-edge domain of computational social sciences, notably topic modelling. The authors argue that a nested application of topic modelling and grounded theory in narrative analysis promises advances in areas where manual-coding driven narrative analysis has traditionally struggled with directionality biases, scaling, systematization, and repeatability. The nested application of the topic model and the grounded theory goes beyond the frequentist approach of narrative analysis and introduces insight generation capabilities based on the probability distribution of words and topics in a text corpus. The authors verify theoretical compatibility through a meta-analysis of a state-of-the-art bibliographic database on energy policy, narratives, and computational social science. Furthermore, they established a proof-of-concept using a narrative-based case study on energy externalities in slum rehabilitation housing in Mumbai, India. It was found out that the nested application contributes to the literature gap on the need for multidisciplinary methodologies that can systematically include qualitative evidence into policymaking. EF

Touching the Invisible: Exploring the Nexus of Energy Access, Entrepreneurship, and Solar Homes Systems in India

Energy Research & Social Science, Volume 69, November 2020, 101767

Venkata Bandi, Tiia Sahrakorpi, Jukka Paatero, and Risto Lahdelma

This study examines the relationship between social entrepreneurship, rural bottom of the pyramid market characteristics, and challenges related to energy access by combining the business model frameworks of social entrepreneurship and off-grid solar. Using narrative theory, it identifies three key activities and associated risks: community engagement, stakeholder management, and organizational capacity building. Social enterprises ought to engage in these three activities in order to manage the high-risk environment in the rural BoP markets. Community engagement bolsters social trust and results in customized solutions for the end user; stakeholder management creates a favourable business environment and is a determinant risk proposition; and finally organizational capacity building enables businesses to deliver reliable services by increasing overall human resource management efficiency, while building social trust. Through a risk assessment of social entrepreneurial activities, practitioners and stakeholders can navigate the risk-based nature of rural SHS markets. EF

Enhancing the Dynamic Performance of Microgrid Using Derivative Controlled Solar and Energy Storage Based Virtual Inertia Systems

Journal of Energy Storage, Volume 31, October 2020, 101613
Pranjal Saxena, Navdeep Singh, and Ashok Kumar Pandey

The micro grid system with a high share of renewable energy sources (RES) is the need of hour. The RES provides clean, economical, and never-ending active power support to the system. However, the inertia deficiency is the negative side of RES-based systems, as it adversely affects the dynamic performance of the micro grid and may lead to severe consequences such as loss of synchronization and instability. For addressing the issue of inertia deficiency, several techniques were already proposed for emulating the virtual inertia. Among these, the derivative control technique (DCT) is quite popular because of its simplicity and effectiveness. This paper proposes a novel technique for tapping the virtual inertia potential of RES (photovoltaic system) by cultivating the derivative control mechanism and further improves the dynamic performance of the system. Further, the efficiency of the proposed system is evaluated through time domain simulations under different scenarios and compared it with conventional and ESS-based systems. EF

Estimation of the Wind Energy Potential for Coastal Locations in India Using the Weibull Model

Renewable Energy, Volume 161, December 2020, Pages 319–339
Sneh Deep, Arnab Sarkar, Mayur Ghawat, and Manoj Kumar Raj

Wind energy has exhibited the fastest growth of all renewable energy sources. Available wind energy potential for use by wind turbines has been found to be highly overestimated by existing methodologies when the wind energy potential is assessed from the total wind speed data because the wind turbine operates between cut-in and cut-out wind speeds. While applying existing methodologies, wind power density is overestimated on average by nearly 25% compared to the actual wind power available to a wind turbine. Hence, for estimating wind energy potential, availability factors and wind energy between cut-in and rated wind speeds should be properly estimated using Weibull models. The appropriateness of different methods of estimating Weibull parameters is site specific. In this article, a novel method has been developed for estimating the actual wind power available to the wind turbine. The parent two-parameter Weibull model can be used to determine the availability factor, whereas when determining the available wind energy between the cut-in and rated wind speeds, wind speed data should be refitted in the range defined by the cut-in and rated wind speeds using a three-parameter Weibull model, where the location parameter can be equated to the cut-in wind speed. EF

Optimum Combination of Renewable Resources to Meet Local Power Demand in Distributed Generation: A Case Study for a Remote Place of India

Energy, Volume 209, 15 October 2020, 118473
Sayan Das, Avishek Ray, and Sudipta De

India has a large population and its fossil fuel-based power is about 70%. Most of the Indian power is supplied by large power plants through the national grid. It is currently facing the formidable challenge to meet the mission: 'clean electricity for all'. Distributed power supply using local renewable resources maybe a better shift from existing practice, specifically for new areas of electrification. This study explores the feasibility of distributed generation with available local renewable resources for a remote village on the Himalayan mountains of a northeast state of India. Currently, electricity in this village through the national grid is unavailable. Villagers are forced to use diesel generator (DG) sets. This study explores the feasibility of using local renewable options to meet the local load demand with a minimum cost of electricity. A minimum COE (cost of electricity) ($0.63/kWh) and CO_2 emissions (481 kg/year) are estimated for optimum uninterrupted power supply. EF

Technology Development for Adsorptive Heat Energy Converters: Emerging Research and Opportunities

Energy saving and emission reduction are two of the greatest challenges facing the world today. Heat energy storage can save fuel and effectively use renewable sources. Heat energy storage is decisive for many energy saving measures and promises a reliance on non-traditional renewable energy sources. However, most recent research focused on material selection is scattered, disembodied, and sometimes contradictory.

This book is an essential publication that offers a cohesive examination of methods of energy storage and conversion. Highlighting a broad range of topics including composite materials, operating principles, and structural characteristics, this book is ideally designed for developers, policymakers, researchers, academicians, students, and engineers in the fields of materials engineering, renewable energy, and environmental engineering. EF

Editors: Kostyantyn M Sukhyy, Elena A Belyanovskaya, and Mikhailo P Sukhyy
Publisher: IGI Global
Year: 2020

100% Clean, Renewable Energy and Storage for Everything

Numerous laws – including the Green New Deal – have been proposed or passed in cities, states, and countries to transition from fossil fuels to 100% clean, renewable energy in order to address climate change, air pollution, and energy insecurity. This textbook lays out the science, technology, economics, policy, and social aspects of such transitions. It discusses the renewable electricity and heat generating technologies needed; the electricity, heat, cold, and hydrogen storage technologies required; how to keep the electric power grid stable; and how to address non-energy sources of emissions. It discusses the history of the 100% movement, which evolved from collaboration among scientists, cultural leaders, business people, and community leaders. Finally, it discusses current progress in transitioning to 100% renewables and the new policies needed to complete the transition. EF

Author: Mark Z Jacobson
Publisher: Cambridge University Press
Year: 2020

Dynamics and Control of Energy Systems (Energy, Environment, and Sustainability)

This book presents recent advances in dynamics and control of different types of energy systems. It covers research on dynamics and control in energy systems from different aspects, namely, combustion, multiphase flow, nuclear, chemical, and thermal. The chapters start from the basic concepts so that this book can be useful even for researchers with very little background in the area. A dedicated chapter provides an overview on the fundamental aspects of the dynamical systems approach. EF

Editors: Achintya Mukhopadhyay, Swarnendu Sen, Dipankar Narayan Basu, and Sirshendu Mondal
Publisher: Springer
Year: 2020

Electrochemical Energy Conversion and Storage Systems for Future Sustainability: Technological Advancements

This book discusses new and well-known electrochemical energy harvesting, conversion, and storage techniques. It provides significant insight into the current progress being made in this field and suggests plausible solutions to the future energy crisis along with approaches to mitigate environmental degradation caused by energy generation, production, and storage.

The book addresses photoelectrochemical catalysis by ZnO, hydrogen oxidation reaction for fuel cell application, and miniaturized energy storage devices in the form of micro-supercapacitors. This book looks at the underlying mechanisms and acquired first-hand information on how to overcome some of the critical bottlenecks to achieve long-term and reliable energy solutions. The detailed synthesis processes that have been tried and tested over time through rigorous attempts of many researchers can help in selecting the most effective and economical ways to achieve maximum output and efficiency, without going through time-consuming and complex steps. The theoretical analyses and computational results corroborate the experimental findings for better and reliable energy solutions. EF

Editors: Aneeya Kumar Samantara and Satyajit Ratha
Publisher: Apple Academic Press
Year: 2020

Renewable-Energy-Driven Future: Technologies, Modelling, Applications, Sustainability and Policies

In order to promote the sustainable development of renewable energy and renewable-energy-driven technologies, this book provides a comprehensive view of the advanced renewable technologies and the benefits of utilizing renewable energy sources.

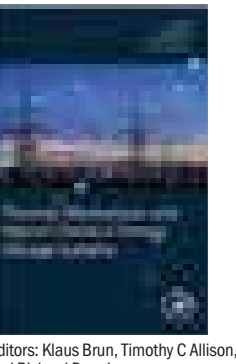
Discussing the ways for promoting the sustainable development of renewable energy from the perspectives of technology, modelling, application, sustainability and policy, this book includes the advanced renewable-energy-driven technologies, the models for renewable energy planning and integration, the innovative applications of renewable energy sources, decision support tools for sustainability assessment and ranking of renewable energy systems, and the regulations and policies of renewable energy.

This book can benefit the researchers and experts of renewable energy by helping them to have a holistic view of renewable energy. It can also benefit the policymakers and decision-makers by helping them to make informed decisions. EF

Editor: Jingzheng Ren
Publisher: Academic Press
Year: 2020

Thermal, Mechanical, and Hybrid Chemical Energy Storage Systems

This book provides unique and comprehensive guidelines on all non-battery energy storage technologies, including their technical and design details, applications, and how to make decisions and purchase them for commercial use. The book covers all short- and long-term electric grid storage technologies that utilize heat or mechanical potential energy to store electricity, including their cycles, application, advantages and disadvantages, such as round-trip efficiency, duration, cost and siting. Also discussed are hybrid technologies that utilize hydrogen as a storage medium aside from battery technology. EF



Editors: Klaus Brun, Timothy C Allison, and Richard Dennis
Publisher: Academic Press
Year: 2020

RENEWABLE ENERGY TECHNOLOGY DEVELOPMENT

New solar panel design could lead to wider use of renewable energy

This study investigates how different surface designs impacted on the absorption of sunlight in solar cells, which put together solar panels. Scientists found that the checkerboard design improved diffraction, which enhanced the probability of light being absorbed. This is then used to create electricity. The renewable energy sector is constantly looking for new ways to boost the light absorption of solar cells in lightweight materials that can be used in products from roof tiles to boat sails and camping equipment. Solar grade silicon used to create solar cells is very energy intensive to produce, and so creating slimmer cells and changing the surface design would make them cheaper and more environmentally friendly.

The investigations showed that their idea actually rivals the absorption enhancement of more sophisticated designs, while also absorbing more light deep in the plane and less light near the surface structure itself. The design rule meets all relevant aspects of light trapping for solar cells, clearing the way for simple, practical, and yet outstanding diffractive structures, with a potential impact beyond photonic applications. It also offers potential to further integrate solar cells into thinner, flexible materials and therefore creates more opportunity to use solar power in more products. The study suggests the design principle could impact not only in the solar cell or LED sector but also in applications, such as acoustic noise shields, windbreak panels, anti-skid surfaces, biosensing applications, and atomic cooling.

Data from the Department for Business, Energy and Industrial Strategy shows renewable energy including solar power made up 47% of the UK's electricity generation in the first three months of 2020.

https://www.sciencedaily.com/releases/2020/10/201008121326.htm

Team extracts more energy from sunlight with advanced solar panels

Silicon solar panels are prevalent because they are affordable and can convert a little over 20% of the sun's light into usable electricity. However, just like silicon computer chips, silicon solar cells are reaching the limit of their abilities, and so finding a way to increase efficiency is attractive to energy providers and consumers.

A team of researchers have been working to layer the semiconductor material gallium arsenide phosphide onto silicon because the two materials complement each other. Both materials absorb visible light strongly, but gallium arsenide phosphide does so while generating less waste heat. In contrast, silicon excels at converting energy from the infrared part of the solar spectrum just beyond what our eyes can see. While gallium arsenide phosphide and other semiconductor materials like it are efficient and stable, they are expensive, and so making panels composed entirely from them is not reasonable for mass production at this time. Hence, the researchers use low-cost silicon as a starting point for its research. During fabrication, material defects find their way into the layers, particularly at interfaces between silicon and gallium arsenide phosphide. Tiny imperfections form whenever materials with different atomic structure are layered onto silicon,

compromising both performance and reliability.

https://www.sciencedaily.com/releases/2020/10/201006114200.htm

New findings pave the way to environmentally friendly supercapacitors

A particularly sustainable, but so far quite unexplored variant of such a hybrid supercapacitor consists of carbon and aqueous sodium iodide (NaI) electrolyte, with a positive battery electrode and a negative supercapacitor electrode. Researchers have investigated in more detail how exactly the electrochemical energy storage in this supercapacitor works and what happens in the nanometer-sized pores of the carbon electrode. The system consists of nanoporous carbon electrodes and an aqueous sodium iodide electrolyte, in other words salt water. This makes this system particularly environmentally friendly, cost-effective, incombustible, and easy to recycle.

With the aid of small-angle X-ray scattering and Raman spectroscopy, the researchers were able to show for the first time that solid iodine nanoparticles are formed in the carbon nanopores of the battery electrode during charging, which dissolve again during discharge. This corrects the previously suspected reaction mechanism and has far-reaching consequences. The degree of filling of the nanopores with solid iodine determines how much energy can be stored in the electrode. This enables the energy storage capacity of the iodine carbon electrodes to reach unexpectedly high values by storing all chemical energy in the solid iodine particles. This new fundamental knowledge opens the way to hybrid super capacitors or battery electrodes with incomparably higher energy density and extremely fast charging and discharging processes.

https://techxplore.com/news/2020-10-pave-environmentally-friendly-supercapacitors.html

Blocking vibrations that remove heat could boost efficiency of next-gen solar cells

A study of a solar energy material with a bright future revealed a way to slow phonons, the waves that transport heat. The discovery could improve novel hot carrier solar cells, which convert sunlight to electricity more efficiently than conventional solar cells by harnessing photogenerated charge carriers before they lose energy to heat. When sunlight strikes a solar cell, photons create charge carriers – electrons and holes – in an absorber material. Hot carrier solar cells quickly convert the energy of the charge carriers to electricity before it is lost as waste heat. Preventing heat loss is a grand challenge for these solar cells, which have the potential to be twice as efficient as conventional solar cells.

The researchers studied methylammonium lead iodide, a perovskite absorber material. In its lattice, collective excitations of atoms create vibrations. Vibrations moving in sync with each other are acoustic phonons, whereas those moving out of sync are optical phonons. To enhance this effect in a photovoltaic perovskite, the researchers used inertia, the tendency of an object to keep doing what it is doing, be that resting or moving. They substituted a lighter isotope of hydrogen, normally occurring protium, which has no neutrons, with a heavier one, deuterium, which has one neutron, in the perovskite's central organic molecule, methylammonium (MA).

https://www.sciencedaily.com/releases/2020/10/201005112123.htm

A home energy management system to achieve optimal control of heat pumps and photovoltaics

The researchers have recently created an energy management system that is specifically designed to modulate photovoltaic (PV) technology and heat pumps residential environments. This new system was developed using JuMP, a modeling framework for mathematical optimization that is embedded in a programming language called Julia. The main goal was to model a comprehensive optimal home energy management system that includes not only PVs and batteries but also a heat pump and thermal storages in order to capture the seasonal effects of sector coupling.

As part of their study, the researchers modelled a hypothetical building powered by a modulating air source heat pump, a PV system, a battery, and thermal storage systems for both floor heating and hot water supply. Their model also includes a grid feed system that ensures that any surplus electricity produced by the PV technology is fed into the grid. The grid feed system implemented by the researchers takes the comfort of residents and fixed feed-in tariffs (i.e., financial incentives offered to renewable energy producers) into account. In addition, the researchers calculated specific target states of charge that could be used as a reference to enhance rule-based energy management systems that are commonly used today.

In the future, the home energy management system could simplify and promote the implementation of technology for the production of renewable energy in residential sites. The Julia JuMP-based model they developed is open source and can be easily accessed online, and thus it could also serve as a reference for other teams who are trying to develop sustainable energy management systems. EF

https://techxplore.com/news/2020-10-home-energy-optimal-photovoltaics.html

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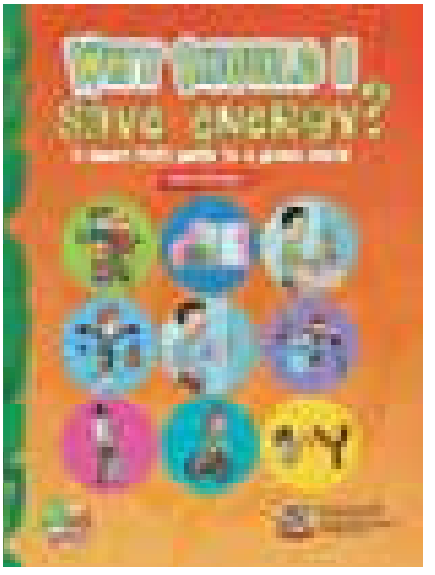

WHY SHOULD I Save eNeRgY?

A smart kid's guide to a green world

Abhas Bhardwaj

• 2020 • 210 x 280 mm • 56 pages
• Hardback • ISBN: 9788179935798
• Genre: Pictorial-Reference • Price: ₹250.00

Ages: 12+ years

Did you know that energy consumption by humans has increased by at least 30,000 times in the last 5000 years? In Delhi alone, there are over 80,000 trucks that run on the city roads every night. They emit un-burnt fossil fuels from their exhausts. Isn't it terrifying that over 1 million seabirds and 100,000 sea mammals are killed by pollution every year?

Why Should I Save Energy? is a comprehensive book that will introduce children to different forms of energy, history of fossil fuels, great scientists and their inventions, and more importantly, to the problems our planet faces with depletion of natural resources. Filled with eye-opening facts, beautiful pictures, multiple activities, and a quiz that helps reinforce learning; this book is the perfect guide to help you become an energy saver.

Table of Contents

About the Author

Abhas Bhardwaj has studied botany and economics. Currently, he works as a market researcher. He has an avid interest in the environment and likes to share his enthusiasm with young minds. In his inimitable style, he likes to approach serious questions with humour.

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NATIONAL AND INTERNATIONAL EVENTS

NATIONAL

International Conference on Sustainable Energy and Future Electric Transportation
January 21–23, 2021
Gokaraju Rangaraju Institute of Engineering and Technology, Hyderabad, India
Website: http://www.sefet.griet.ac.in/

AREEV-2020: International Conference on Advances in Renewable Energy & Electric Vehicles
December 22–23, 2020
Nitte, India
Website: https://easychair.org/cfp/AREEV-2020

World Solar Congress
February 18, 2021
Taj Lands End, Mumbai
Website: https://worldcsrday.com/world-solar-congress/index.html

World Renewable Energy Technology Congress & Expo
December 15–16, 2020
New Delhi, India
Website: http://wretc.in/about_WRETC-&-Expo.html

International Conference on Mathematical Modeling, Computational Intelligence Techniques and Renewable Energy
February 6–8, 2021
Gandhinagar, Gujarat, India
Website: http://mmcitre.com/

INTERNATIONAL

2021 7th International Conference on Renewable Energy Technologies (ICRET 2021)
January 8–10, 2021
Kuala Lumpur, Malaysia
Website: http://icret.org/ (virtual conference)

SEGT 2020-21 Conference
December 12–15, 2020
InterContinental Saigon Hotel, Ho Chi Minh City, Vietnam
Website: https://www.isegt.org/

2020 International Conference on Environmental Science and Renewable Energy
December 28–30, 2020
Hong Kong
Website: http://www.esre.net/

2021 6th International Conference on Renewable Energy and Conservation (ICREC 2021)
January 3–5, 2021
Shenzhen, China
Website: www.icrec.org/

2021 Renewable Energy Summit
January 12–14, 2021
Madison, Wisconsin, USA
Website: www.renewwisconsin.org

RENEWABLE ENERGY AT A GLANCE

Ministry of New & Renewable Energy			
Programme/Scheme wise Physical Progress in 2020-21 & Cumulative up to Sept 2020			
Sector	**FY- 2020-21**		**Cumulative Achievements**
	Target	**Achievements (April-Sept 2020)**	**(as on 30.09.2020)**
I. GRID-INTERACTIVE POWER (CAPACITIES IN MWp)			
Wind Power	3000.00	380.40	38,124.15
Solar Power - Ground Mounted	9000.00	721.93	32,834.42
Solar Power - Roof Top	2000.00	700.98	3216.28
Small Hydro Power	100.00	56.80	4739.97
Biomass (Bagasse) Cogeneration	200.00	173.37	9373.87
Biomass (non-bagasse) Cogeneration)/Captive Power	50.00	97.24	772.05
Waste to Power	30.00	21.00	168.64
Total	**14,380.00**	**2151.72**	**89,229.38**
II. OFF-GRID/CAPTIVE POWER (CAPACITIES IN MW_{EQ})			
Waste to Energy	10.00	6.53	204.73
SPV Systems	500.00	27.07	1005.46
Total	**510.00**	**33.60**	**1210.19**
III. OTHER RENEWABLE TECHNOLOGIES(Capacity in Nos.)			
Biogas Plants(in Lakhs)	0.60	0.09	50.50

Source: www.mnre.gov.in