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Electric Energy Society of Australia

NATIONAL BULLETIN

Bulletin 2 | 2022

Feedback on AEMO's draft 2022 Integrated System Plan

By Jeff Allen, National President of the Electric Energy Society of Australia | 18 February 2022

In the January Bulletin I wrote about "Our Energy Future – what will be the key changes?" and this included a mention of AEMO's latest draft 2022 Integrated System Plan (ISP) which was published on 10 December 2021. The ISP sets out a roadmap for the development of eastern Australia's electricity system. I also indicated that stakeholder consultation on the Draft 2022 ISP, including public forums and written submissions, was open until 11 February 2022 and that EESA had a small team (Terry Lampard, Dr Robert Barr, and Bruce Howard) collaborating with several other experts in reviewing and providing comment on the draft plan so that Engineers Australia's could provide a submission to AEMO.

The Engineers Australia submission on the Draft ISP was sent to AEMO on 11th February and in summary it indicated that the ISP could be enhanced through:

- "Providing more complete and transparent modelling, particularly demand modelling that includes worst case scenarios for minimum and coincident minimum demand, as well as worst case scenarios for renewable generation. It is not always apparent how the conclusions contained in the ISP have been drawn. It would be greatly beneficial to provide enough detail that experienced engineers can validate the credibility of the ISP scenarios.
- Maintaining and improving the reliability and security of the power system by prioritising the technical requirements and system control engineering ahead of 'market' concerns. Without appropriate primary controls in place the system will be vulnerable.
- Providing end-to-end costings to bring greater clarity on the total impact on future delivered electricity costs.
- Providing greater confidence in the ISP through contextualisation in the broader Australian context, such as key interfaces, relationships, and dependencies.
- Greater consideration of the impact of the rapid increase in DER on distribution network regulatory frameworks and market models, particularly as DER penetration increases."

Jeff Allen, National President of the Electric Energy Society of Australia

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The submission also indicated that a better understanding of the workforce skills and overall numbers was required to ensure that the transition outlined in the ISP is achievable. This is consistent with the views of industry organisations who are concerned regarding a looming gap in overall numbers of people and the engineering "know how" required to facilitate the "electrification" of Australia's future energy needs.

One of the areas of concern in reviewing the Draft ISP, was that there was a lack of focus on distribution networks, particularly around DER (Distributed Energy Resources) integration, MV and LV storage and the impacts of Electric Vehicles. There is a view that the Draft ISP assumes that all DER generation can be exported into the network. There is, however, a widely held view that this is not going to be possible without additional investment in the distribution network (either through traditional network capacity augmentation, investment in energy storage or through the development of more innovative 'active management' approaches such as dynamic network monitoring, state estimation and dynamic operating envelopes – or a combination of all approaches.

One of the concerns also coming out of the review of the draft ISP is how does the ISP consider the renewable energy generation (particularly solar) that connects directly to the DNSP networks? As this is not fully scheduled generation, it is not automatically identified by AEMO. There are currently many active commercial projects in the sub 5 MW range which are often aggregated to form a larger commercial generation entity. Is AEMO underestimating this generation segment within the DNSP network as AEMO has no visibility of the projects commissioned or underway? Will this result in load forecasts at TNSP bulk supply points being distorted - i.e., unrealistically high? If this is the case it could then have a follow-on effect of unnecessary transmission augmentations being planned.

The general point made in the contribution to the draft ISP is that AEMO needs to engage far more extensively in detail with DNSPs to ascertain such information together with associated network modelling down to DNSP zone substation level through to the LV system as it appears that current AEMO modelling only extends to TNSP bulk supply points.

Interestingly, Dr Robert Barr – EESA's past National President - has separately submitted comments on the draft ISP via his consulting company (Electric Power Consulting) and has provided feedback on

- "The technical viability of the mix of transmission, generation and storage specified in each of the scenarios to meet the specified customer loads.
- The quality of financial analysis and the identification of areas where improvements can be made."

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In reading EPC's submission, he has undertaken considerable modelling and his submission indicates significant differences between AEMO's modelling and EPC's modelling. His comments include the statement that "The ISP aim should be to minimise the total cost of electricity supply to customers, not just to minimise the NPV cost of transmission, HV generation and grid storage. The scope of the electricity costs needs to include:

- Grid connected generation (both DNSP and TNSP)
- Transmission
- Grid connected storage (both DNSP and TNSP)
- All sub transmission (both conventional load and REZ (Renewable Energy Zone developments)
- All LV and MV distribution
- All behind the meter generation and battery storage
- Retail and metering"

He is also of the view that AEMO's draft ISP "needs to become more customer focused and show comparable HV and LV customer delivered costs in $/MWh for each year through to 2050 for all the scenarios".

In summary, AEMO has received significant feedback on the draft 2022 ISP and all of the 62 submissions can be accessed via the following link - https://aemo.com.au/consultations/current-and-closed-consultations/2022-draft-isp-consultation

The announcement by Origin Energy on Thursday 17th February that they are bringing forward the closure of the Eraring Coal Fired power station – Australia's largest power station with a capacity of 2,880 MW by 7 years to 2025 - will also have an impact on the final 2022 ISP.

It will be interesting to read the final 2022 ISP.

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BASS LINK CONTRACT TERMINATED

By Guy Barnett, Tasmanian Minister for Energy and Emissions Reduction | 10 February 2022 | Source: Tasmanian Govt

Consistent with the Tasmanian Government and Hydro Tasmania's decision in November last year to protect and progress Tasmania's legal rights in relation to the Basslink cable, Hydro Tasmania has taken another step in that process terminating the Basslink Services Agreement (BSA).

This follows the 2020 arbitration concerning the cause of the 2016 major Basslink outage, which found in the State and Hydro Tasmania's favour, confirming the link cannot meet the capacity requirements set out in the BSA and that the owner of Basslink should pay compensation to the State.

Since November last year, Hydro Tasmania along with the State, has been in negotiations with the receivers of Basslink regarding an alternative commercial arrangement.

The termination of the BSA will not impact Tasmania's energy security, which remains on firm footing, with very strong hydro storage levels, the Cattle Hill and Granville Harbour wind farms, while the cable will remain in service.

The Tasmanian Government and Hydro Tasmania will continue to engage with Basslink's financiers and receivers on alternative commercial arrangements, suitable for the receivership period.

Tasmanians can be assured that our energy security is stronger than ever and that the Government will continue to act in the best interests of Tasmanians.

BASS STRAIT SURVEY BEGUN FOR MARINUS LINK

By Marinus Link Project | 13 February 2022 | Source: Marinus Link

An 87-metre long ship, the TEK Ocean Spirit, has departed the Port of Burnie for Marinus Link's largest underwater engineering survey of Bass Strait. The survey will help refine the final design and installation methodology for the proposed interconnector cable.

Marinus Link Pty Ltd, a wholly-owned subsidiary of TasNetworks, announced last year an Australian company, MMA Offshore, won the $5.5 million contract to carry out critical engineering surveys, known as the Marine Engineering Geotechnical Site Investigation (MEGSI).

The 32 expert crew aboard the survey ship TEK Ocean Spirit left the Port of Burnie on Friday 11 February and will take between four to six weeks to survey the 255 kilometres between Heybridge in North West Tasmania and Waratah Bay in South Gippsland, Victoria.

LOCAL NEWS

The survey will be conducted on approximately 110 sites across Bass Strait, in sea depths up to 80 metres. It is Marinus Link's third major marine survey undertaken to determine the most suitable corridor for burying the project's undersea cables.

Marinus Link Pty Ltd CEO Bess Clark said this survey is another demonstration of Marinus Link's commitment to rigorous technical processes to sensitively design and build this national-priority infrastructure.

"Marinus Link is key to Australia's clean energy future – increasing reliability, placing downward pressure on electricity prices and cutting emissions by making the most of our high quality renewable energy resources," Ms Clark said.

"Marinus Link, together with augmentations to Tasmania's electricity network, is well underway and has passed a Regulatory Investment Test for Transmission (RIT-T) overseen by the independent Australian Energy Regulator (AER).

"The project is critical to supporting Australia's energy transition, with the Australian Energy Market Operator (AEMO) confirming Marinus Link will deliver significant benefits to consumers both in Tasmania and across the broader National Electricity Market. AEMO has called for the project to be delivered as early as possible.

"The project will deliver thousands of clean energy jobs to regional communities in Tasmania and Victoria. By awarding this major $5.5m contract to Australian company MMA Offshore, we are proud to be supporting Australian businesses as we progress a critical piece of the nation's clean electricity grid.

"We are committed to preserving our sensitive marine and land environments as we progress this project, and will keep work closely with stakeholders to listen to and learn from the local community."

"Marinus Link is giving Burnie the chance to play a critical role in Australia's clean energy future," said Mayor of Burnie Steve Kons.

"We can be proud as locals about this national-priority infrastructure, which will boost our local economy and jobs. "Local businesses in Burnie will help supply food, fuel and services for the TEK Ocean Spirit and its crew, which will provide an almost immediate economic benefit to our local area," he said.

The ship and its crew from Tasmania, Western Australia and Victoria has been based in Port Anthony (Victoria) getting fitted out for the survey for several weeks in the lead up to departure.

"This survey builds on the results and analysis of previous surveys we have conducted. The locations chosen to take samples have been selected to minimise the impact on the seabed floor, reefs and marine life," said Offshore Lead for Marinus Link, Sean Van Steel.

For video footage of the TEK Ocean Spirit and interviews with Marinus Link CEO Bess Clark, Marinus Link Project Director Steven Clark and Offshore Lead for Marinus Link Sean Van Steel, please visit this link. For images of the vessel please visit this link.

LOCAL NEWS

the TEK Ocean Spirit

Background

The $3.5bn ($2021) Marinus Link interconnector is a proposed 1500 megawatt electricity and telecommunications connection between Victoria and Tasmania.

Marinus Link involves approximately 255 kilometres of undersea High Voltage Direct Current (HVDC) cable and approximately 90 kilometres of underground HVDC cable, plus converter stations in Tasmania and Victoria. The supporting North West Transmission Developments in North West Tasmania involves the construction of approximately 240 kilometres High Voltage Alternating Current (HVAC) transmission lines.

Marinus Link will unlock emission reductions of at least 140 million tonnes of CO2 by 2050, the equivalent of taking approximately a million petrol/diesel cars off the road.

1500 megawatts equates to supplying approximately 1.5 million Australian homes with electricity at any given time. Project Marinus (Marinus Link plus North West Transmission Developments) will create at least 2800 direct and indirect jobs through construction, with direct economic investments in regional areas of approximately $3bn.

LOCAL NEWS

WESTERN POWER LAUNCHES AUSTRALIA'S LARGEST MICROGRID

By Western Power | 2 February 2022 | Source: Western Power

WA Energy Minister Bill Johnston has launched the $15 million Kalbarri microgrid, the largest of its kind in Australia, providing a reliable power supply for this remote community. The project is a blueprint for the delivery of innovative energy solutions throughout Western Australia.

Using entirely renewable wind and solar energy the micro-grid will provide greater power reliability for local tourism and retail operations, and for the broader community.

Microgrids are increasingly being used as a more resilient method to deliver electricity to rural communities as the design is less likely to be interrupted by environmental factors.

Western Power developed the Kalbarri microgrid in partnership with Synergy, the Shire of Northampton and the local community.

LOCAL NEWS

Comments attributed to Energy Minister Bill Johnston

"Improving how energy is delivered in regional areas and delivering better power reliability for Western Australians is an important part of the McGowan Government's Distributed Energy Resources Roadmap.

"The Kalbarri microgrid is an important step towards improving power reliability for the local community.

"It also paves the way in delivering greater renewable energy solutions across WA, particularly in regional areas, as we move forward in achieving net zero emissions by 2050."

Comments attributed to Mining and Pastoral Region MLC Peter Foster

"Kalbarri is a tourism drawcard with more than 100,000 visitors flocking to the beachside town each year.

"The new microgrid is one of Australia's most sophisticated, and will be used as a blueprint for other regional areas to support the provision of stable, secure and clean energy into the future."

LOCAL NEWS

If you'd like to find out more about the Kalbarri microgrid, including a tour inside the microgrid, community stories and a full overview of the project visit the Kalbarri microgrid project page.

WA INTRODUCES ROOFTOP SOLAR REMOTE CONTROL RULES

By Tamatha Smith | 17 February 2022 | Source: Energy Insider

Rooftop solar installations in Western Australia have increased more than 600 per cent[1] over the past decade, with 36 per cent of the State's customers now generating their own electricity. While this huge influx of renewable energy is great for customers and our net zero ambitions, it presents major challenges for the electricity system. New rules came into effect this Valentine's Day to help manage this and enable WA's love affair with rooftop solar to continue.

With these new emergency solar management requirements, WA joins South Australia as the first two jurisdictions in Australia to require that new and upgraded rooftop solar can be remotely turned down or switched off in emergency situations, where system reliability and security are at risk. The rules are part of a suite of policy, regulation and system changes being implemented as part of WA's Energy Transformation Strategy.

LOCAL NEWS

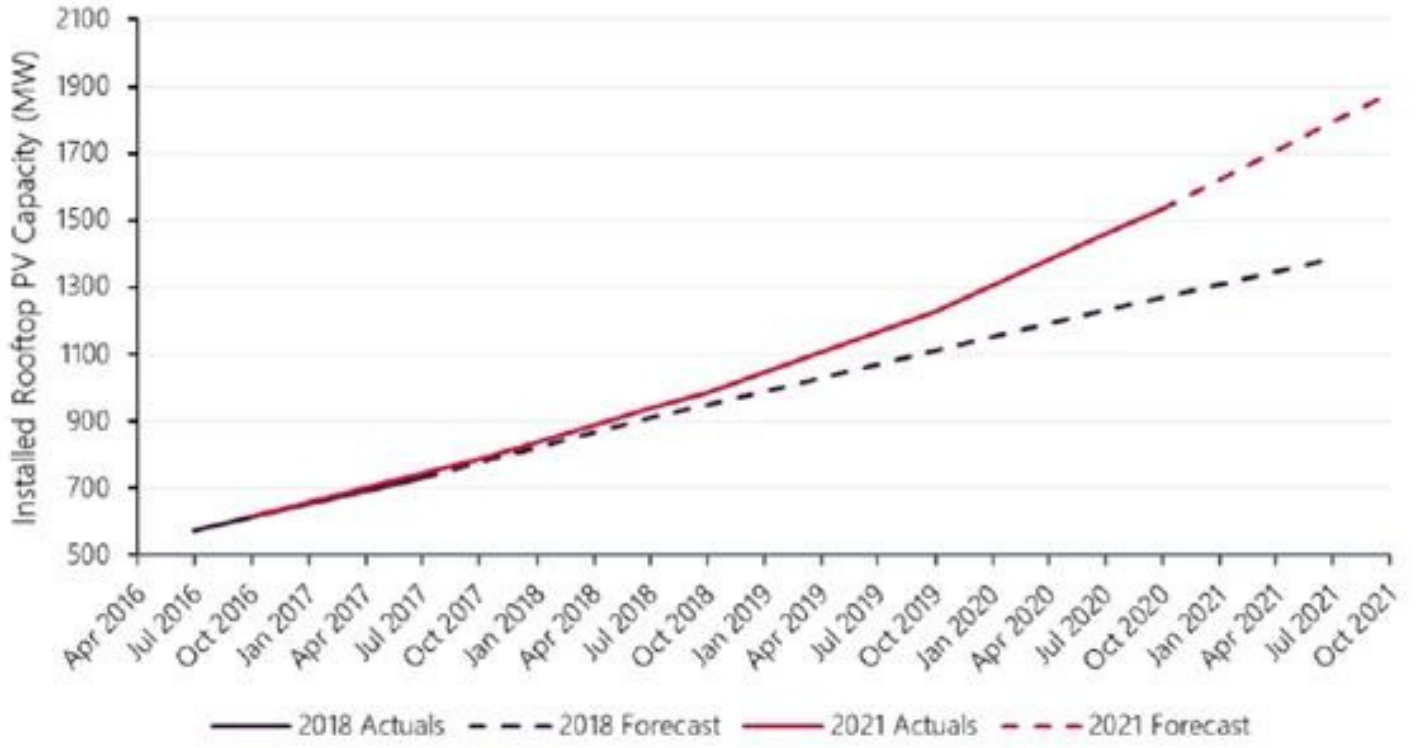
According to Energy Policy WA, the new requirements will:

- only apply to new and upgraded rooftop solar – existing customers will be unaffected.
- only be used in emergencies – expected to be needed infrequently and for short periods and will prevent loss of power for consumers during these critical times.
- not interrupt power supply to customers – only rooftop solar generation is reduced, and customers will continue to receive power from the grid.
- only impact households as a last resort – other options to protect the power system, including turning down large-scale generators, will be exhausted first; and
- allow more renewables overall – by managing risks during these infrequent emergency times, greater levels of rooftop solar installation will be possible.

The new rules are intended to work as a last resort with a host of other new capabilities and policies being introduced to support renewable integration in the grid. These include the Kwinana "big battery", community battery trials, Western Power's Flexibility Services Pilot, virtual power plants and tariff reforms to encourage customers to use more energy in the middle of the day to soak up solar generation.

The solar emergency intervention capacity has become critical as WA's rooftop PV installations have rapidly accelerated. Its speedy introduction was a recommendation of the Australian Energy Market Operator (AEMO) in its 2021 Renewable Energy Integration – SWIS Update report.

Figure 1 AEMO Renewable Energy Integration – SWIS Update 28 September 2021



LOCAL NEWS

At 1362MW, the combined residential solar output from all this distributed renewable rooftop generation now exceeds that of WA's biggest power station – Synergy's 854MW Muja Power Station.

This renewable transition presents great opportunities for customers, but the plummeting demand from the grid during times when solar is generating (known as low-load or minimum demand) makes the electricity system vulnerable.

When demand is extremely low, it creates voltage instability that if not checked could cause widespread power outages.

Figure 2 Why solar management is needed: Source: Energy Policy WA

Western Australians continue to embrace rooftop solar, known as distributed photovoltaic (DPV), at an unprecedented rate. In 2020 alone, installed DPV capacity increased by a record over 300 megawatts (MW).

About one in three households have installed DPV systems, and solar generation is already providing up to 64% of our total electricity needs during the middle of the day. This phenomenal uptake is transforming the way we generate and supply electricity.

However, rapidly growing levels of solar generation is presenting risks to the operation of our power system.

These risks arise when generation from solar is high and our demand for electricity from the grid is very low – this is known as 'low load'. This typically happens on mild, sunny weekend days in Autumn and Spring, when demand from businesses is relatively low and air-conditioning is unnecessary for most customers.

At these times, fewer large thermal generators are required to operate as there is lower demand. However, these generators provide critical services to our power system, stabilising electrical frequency on the grid, helping the power system to ride through disturbances (such as transmission line outages), and responding rapidly to sudden changes in demand and supply. Without a minimum level of thermal generation, our power system becomes vulnerable to widespread outages.

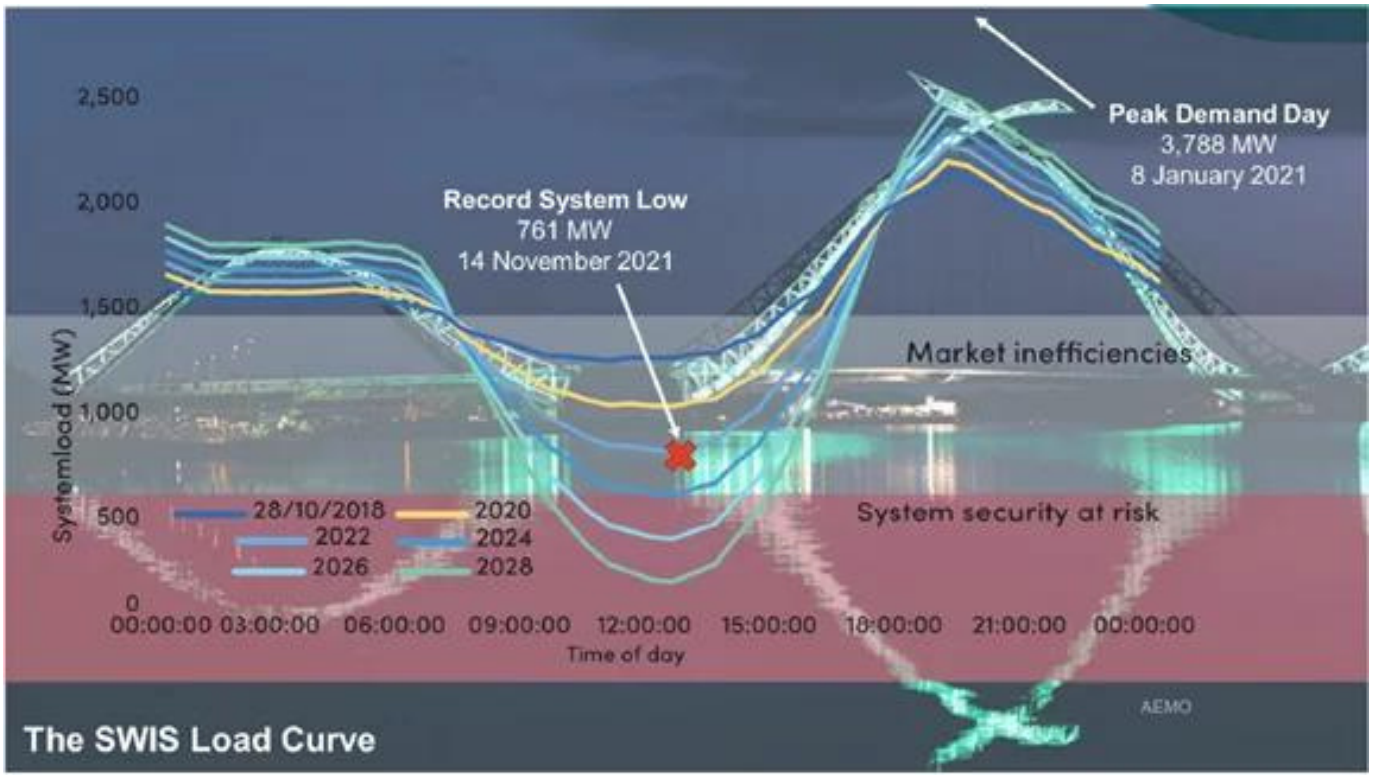
LOCAL NEWS

The graph below (source: EPWA) represents what those in the energy industry know as the solar "duck curve" – though in WA's case the problem is becoming so severe the duck looks more like a swan. The low demand on the system is represented by the belly of the duck, with corresponding peak demand as the sun goes down and solar stops generating.

As more solar is adopted, demand plunges in the middle of the day and peaks higher and earlier in the evenings as all the self-generators turn back to the grid for power.

AEMO has forecast that WA faces system security risks by 2024, based on current solar adoption rates.

Figure 3 WA's swan curve



WA's Energy Transformation Strategy and the policy and system changes being introduced by government, Western Power and other key energy industry stakeholders were developed in anticipation of the challenges presented not just by rooftop solar, but also the growth in utility-scale variable renewable generation.

The new emergency solar management capacity is only part of the toolkit, but it is a vital last resort measure. The impact on customers will be minimal and their power supply will not be impacted when their solar is "managed", but the support it provides to the electricity system will be critical.

As well as helping prevent outages, being able to manage the risks during emergency times will mean more rooftop solar installations will be possible.

LOCAL NEWS

Future changes will include the capacity for customers with solar, batteries and EVs to participate in the energy market and be paid to provide system services – like stored energy at peak times or switching off solar at low-demand times. Community batteries can also be used to provide these services, benefiting the customers participating in these programs. These are just a few of the huge and complex changes underway.

The WA Government, Western Power, Synergy and industry stakeholders are to be congratulated for the planning and progress being made to enable the State's transition to renewable energy.

For more information, check out the EPWA website.

KIDSTON 250MW PUMPED HYDRO TO USE DISUSED MINING PITS

By Ruth Cooper | 17 January 2022 | Source: Create Digital

The Kidston Pumped Storage Hydro Project will repurpose old mine pits.

LOCAL NEWS

Construction is underway on an innovative engineering project that will turn two retired mining pits in Queensland into a pumped hydro energy storage facility.

Led by Genex Power, the 250 MW Kidston Pumped Storage Hydro Project at the old Kidston gold mine, 270 km north-west of Townsville, is the first pumped hydro power station to be built in Australia in almost 40 years.

Planned for commissioning in 2024, the project will involve building an upper-level dam, or 'turkey's nest', around the top of the uppermost mine pit. Water stored in this upper reservoir will fall some 220 metres down two vertical inlet shafts through reversible turbine-generators into the lower reservoir to generate electricity.

Energy Australia has entered into a 30-year offtake agreement with Genex and will sell the energy into the National Electricity Market.

The facility will have 250 MW generating capacity and energy storage capacity of 2000 MWh in the top reservoir. This storage equates to eight hours of generation at full load, or enough to power 143,000 homes. It will have a start up time of less than 30 seconds, allowing it to respond quickly to any shortages of electricity supply.

Engineers Australia Fellow Dr Ralph Craven FIEAust has been the Chair of Genex since 2014. As a young electrical engineer he was involved in the development of Australia's last pumped hydro project, the Wivenhoe Power Station, in 1984.

Craven said the engineering challenges on such a unique project — which Genex describes as a world-first — are "quite extensive" but that the position and size of the Kidston mine pits made them ideal for repurposing.

An aerial view of the Kidston site.

LOCAL NEWS

"Wonderfully, the elevation of one of the pits is some 200 metres above the other, and they're only 400 metres apart," Craven told create.

"This meant we could configure a power station arrangement where you could run the water from the top with a natural head, through the power station and into the bottom pond and then pump it back up."

The downside is there is currently no way of getting the energy to consumers. This will be addressed through the construction of a new 186 km, 275 kV transmission line between Kidston and a new switchyard at Mount Fox. This is east of Kidston and will connect with the existing Ross to Chalumbin 27 5kV transmission line.

"Having a 250 MW pumped storage power station right in the centre of the north Queensland network, connected by the new transmission line, provides additional system strength to the whole of the north Queensland transmission network," Craven said.

"By providing this system strength, as well as voltage and frequency control features, the Kidston pumped storage hydro power station will enable more renewable projects to be developed in the north Queensland region."

The pumped hydro facility is the centrepiece of what will become the Kidston Clean Energy Hub, which will eventually incorporate solar, wind and hydro electricity generation.

There is already a 50 MW solar project operating at the site, with a larger solar farm and 150 MW wind projects currently in the feasibility stages of development.

"HAVING A 250 MW PUMPED STORAGE POWER STATION RIGHT IN THE CENTRE OF THE NORTH QUEENSLAND NETWORK, CONNECTED BY THE NEW TRANSMISSION LINE, PROVIDES ADDITIONAL SYSTEM STRENGTH."
Dr Ralph Craven FIEAust

Tackling the engineering challenges

While pumped hydro facilities are already in operation around Australia – including the Snowy Hydro Tumut 3 power station, Shoalhaven Hydro in Kangaroo Valley and Wivenhoe Power Station near Brisbane – the Kidston Pumped Hydro Project is unprecedented in its re-use of retired infrastructure.

But this isn't the only challenge. The project also requires significant underground infrastructure, including a large powerhouse cavern and waterway shafts and tunnels to transfer water between the upper and lower reservoirs to generate power during peak periods. The water will then be returned to the upper reservoir using reversible pump turbines when there is an abundance of low-cost renewable power.

LOCAL NEWS

A 50 MW solar project is already in operation at the site.

"We have to pump out the majority of the existing water in the bottom pond so that we can build the water intake and exit infrastructure for the underground power station," Craven said.

"It's an engineering exercise in itself just to manage what we've got to repurpose and make the most of the opportunity." Genex Chief Operations Officer Arran McGhie has spent the majority of his 26-year career in underground mining, tunnelling and civil infrastructure. He said the placement of excavations, and in particular the location of the underground power station, was crucial to ensure the project avoided some major geological faults.

"Significant geotech investigations and the construction of a very detailed 3D Leapfrog geological model was required," he told create.

The stability of the walls of the lower pond was also a potential issue.

"We had to work closely with our EPC contractor, McConnell Dowell John Holland Joint Venture, to derive construction methodologies to enable the scheme to be constructed from a single decline access tunnel, including the tailrace tunnels and portal structures," McGhie said.

"This meant we could avoid undertaking extensive wall stability works around the entire lower reservoir."

Despite, or perhaps because of, the vast challenges, McGhie said it is a privilege to be part of the Kidston project. "The hydro project is totally different to any other project I have worked on as it brings together almost any construction methodology and engineering disciplines you care to think of," he said.

"There are numerous engineering challenges, including the need to relocate 28 gigalitres of water from the lower reservoir to the upper reservoir to facilitate the construction of the underground power station and its entry and exit works. This is a major undertaking in its own right."

LOCAL NEWS

HOUSEHOLD GAS USE MUCH WORSE FOR HEALTH AND CLIMATE THAN FIRST THOUGHT

By Michael Mazengarb | 28 January 2022 | Renew Economy

New research has found pollution and greenhouse gas emissions from household gas use is much larger than first thought. (Photo credit: Canva)

Stanford University researchers have concluded that the health and environmental impacts of the use of gas stoves are much worse than previously suggested, largely due to the release of unburnt methane into the atmosphere. This international study has implications for the debate about the future of gas usage in Australia.

The results of the latest study have been published in the journal Environmental Science and Technology, and examined the emissions produced by 18 brands of gas cooktops and stoves across a wide range of appliance ages.

The researchers found that an estimated 1.3 per cent of fossil gas used in household stoves is released into the environment as unburnt methane.

Methane, which is the main constituent of fossil gas, is a potent greenhouse gas with a global warming potential that is 28 times greater than carbon dioxide over a 100-year period.

The researchers also monitored the amount of gas released by gas appliances when they are turned off, leading to the "surprising" discovery that around three-quarters of the methane released by stoves resulted from gas escaping through fittings and connections.

"There are very few measurements of how much natural gas escapes into the air from inside homes and buildings through leaks and incomplete combustion from appliances," study lead author Eric Lebel from Stanford's School of Earth, Energy and Environmental Sciences, said.

"It's probably the part of natural gas emissions we understand the least about, and can have a big impact on both climate and indoor air quality."

Previous studies had generally overlooked gas that escaped from appliances when they were not being used, which the researchers suggest has led to a significant underestimate of the emissions released by household gas appliances.
"We quantified steady-state-off emissions from stoves because they were not included in most previous cooktop emissions studies and because, previously, we found steady-state-off emissions to be a substantial, sometimes dominant, component of total methane emissions from storage water heaters," the study says.

LOCAL NEWS

The paper suggests that because the amount of methane release while stoves are not being used has not previously been measured in detail, the amount of residential greenhouse gas emissions may have long been underestimated.

Using the United States as an example, the study estimated that the greenhouse gas emissions footprint of residential gas stoves from use and through the leakage of gas was the equivalent of 500,000 petrol-fuelled cars.

The study also found that gas stoves were responsible for the release of significant levels of other air pollutants into homes, including nitrous oxides, noting that the appliances were somewhat unique for releasing exhaust gases directly into living spaces.

"Among all gas appliances, the stove is unique in that the by-products of combustion are emitted directly into home air with no requirement for venting the exhaust outdoors," the study says.

"In fact, some kitchens have "ductless" hoods that recirculate fumes through activated charcoal filters, which are generally less effective at cleaning the air."

The US-based study found that households that use gas stoves without a rangehood or with poor ventilation could surpass Environmental Protection Agency guidelines for exposure to nitrogen dioxide.

Senior author of the study, Rob Jackson of Stanford University's Earth System Science department, said there needed to be some consideration of how these risks can be eliminated.

"I don't want to breathe any extra nitrogen oxides, carbon monoxide or formaldehyde," Jackson said.

"Why not reduce the risk entirely? Switching to electric stoves will cut greenhouse gas emissions and indoor air pollution." Gas companies have gone to great lengths to convince people that they should prefer using gas stoves for cooking, even commissioning Instagram influencers to promote using gas to their followers.

Electric stoves, including induction hotplates, provide a gas-free alternative that can avoid the release of methane and other pollutants into people's homes and be entirely emissions-free when powered by renewable electricity.

Last year, a report published by the Climate Council detailed how residential gas use was estimated to be responsible for around 12 per cent of the childhood asthmas burden, finding the health risk for children was comparable to living in a household with cigarette smoke.

ELECTRIC VEHICLE NEWS

RMIT ESTABLISHES EV RESEARCH FACILITY

By Michael Quin | 15 February 2022 | RMIT news

The first electric vehicle research facility of its kind in the southern hemisphere will be established at RMIT University in the heart of Melbourne's CBD.

Supporting the Electrification of Victoria's Future Fleet is a major project bringing government, university and industry partners together around the expertise and infrastructure needed to support widespread adoption of electric vehicles in Victoria.

The $5.2 million funding was announced today by the Hon Gayle Tierney MLC under the Victorian Higher Education State Investment Fund (VHESIF).

It marks an important step towards the state's net zero targets, while boosting skills and employment for Melbourne's pandemic recovery.

With transport responsible for around 25% of greenhouse gas emissions in Victoria, Minister Tierney said electrification of transport was critical for tackling climate change, as well as creating new jobs in low-carbon industries.

"This is an important project for the future of clean, green transport in Victoria but also for our plan to meet net zero emissions by 2050 through innovative research and the development of new technology," Tierney said.

"We know our local universities have a lot to offer which is why we're working with them, and industry, to build a bright future – while also creating great study, research and job opportunities for Victorians."

RMIT Deputy Vice-Chancellor Research and Innovation and Vice-President, Professor Calum Drummond, said activity would focus around a new Electric Vehicle Living Lab with EV charging stations, regenerative grid and battery simulators and more.

Left to right: Sheena Watt MP (Member for Northern Metropolitan Region), Professor Alec Cameron (RMIT Vice-Chancellor and President), Professor Susan Dodds (Deputy Vice Chancellor Research and Industry Engagement, Latrobe University), Dr Leonie Walsh (Chair, C4NET), Dr Amanda Caples (Victoria's Lead Scientist), Professor Calum Drummond (RMIT Deputy Vice-Chancellor Research and Innovation and Vice-President), Liam Henderson (Energy Innovation Lead, City of Melbourne) and Peter McTaggart (Manager AI and Data Analytics Citipower & Powercor).

ELECTRIC VEHICLE NEWS

This critical infrastructure will build on RMIT's existing microgrid and renewable generation facilities.

"We'll be developing cutting-edge battery technology and simulating the impacts of widescale electric vehicle adoption on electricity grid loading, prices and the broader system," Drummond said.

"As well as applied technology development, a full-scale applied research project will inform policy towards Victoria's net zero emission targets in the transport sector, proactively addressing both likely and unforeseen challenges as electric vehicles are adopted at accelerated rates."

Research lead, RMIT's Associate Professor Mahdi Jalili, said as well as studying the impact of electric vehicles on the grid, they would also investigate opportunities for electric vehicles to actually support the grid, thus improving the security, reliability and affordability of electricity supply.

The RMIT-led consortium includes Monash and La Trobe universities and industry partners Siemens, City of Melbourne, Centre for New Energy Technologies (C4NET) and CitiPower/Powercor.

Their joint projects will all focus on the mission of ensuring a smooth transition to sustainable transport in Victoria and supporting the state's targets, including development of a zero-emission public bus fleet by 2025, and having half of all new car sales zero emission by 2030.

To this end, the lab will also act as an analysis platform to support critical Victorian Government initiatives and trials. This includes an upcoming study by RMIT and industry partners into the cost, befits and impact of zero emission buses on the electricity grid, based on the government's three-year electric bus trial.

CEO at C4NET, James Seymour, said in addition to C4NET's support of EV research, the development of a consolidated electric vehicle data repository would be another major outcome.

This will include valuable, real-world data on travel patterns, user behaviour, customer responses to tariff signals and details on the performance of various battery technologies.

CEO at C4NET, James Seymour

"This publicly available dataset will support electric vehicle research in Victoria, nationally and internationally, filling a critical gap in capability and complements C4NET's broader data access service from Victoria's 2.7 million smart meters," Seymour said.

The Electric Vehicle Living Lab at RMIT will also provide hands-on learning opportunities for students.

The VHESIF funding initiative behind this announcement was developed in response to the significant impact of the coronavirus pandemic on universities. The investment in RMIT to support pandemic recovery and renewal in Melbourne comes after $44.6 million in round one VHESIF funding last year for development of RMIT's Social Innovation Precinct.

ELECTRIC VEHICLE NEWS

VOLKSWAGEN EVs TO HAVE BI DIRECTIONAL CHARGING, ALLOWING THEM TO POWER HOMES

By Bridie Schmidt | 17 February 2022 | The Driven

The batteries in Volkswagen electric cars will be able to provide power to homes by the end of 2022, VW boss Herbert Diess said today.

The capability will be able to be activated for models with 77kWh batteries via an over-the-air software update, Diess said in an "ask me anything" session on social media forum Reddit.

"Bidirectional charging will be available this year for all ID. Models with 77 kWh battery, also via OTA update. In the beginning we will only offer Vehicle-to-home. This means you can run your dishwasher with electricity from abroad," he said.

While we're not exactly sure what he meant by "from abroad", the statement about vehicle-to-home (V2H) or bidirectional charging was one of a few illuminating responses from the VW boss.

Volkswagen first touted adding vehicle-to-grid (V2G) in its cars in 2021, and the latest statements hint that bidirectional capabilities in cars with CCS2 plugs could come soon.

Diess's goal to roll out vehicle-to-home charging by the end of 2022 is dependent on the finalisation of a CCS2 plug standard to allow bidirectional charging; currently, it is only possible via the CHAdeMO plug standard.

V2H also requires installation of a bidirectional charger. Volkswagen first introduced a 22kW bidirectional DC charging station in 2020, which it deployed across 20 sites for testing.

It is also dependent on regulatory approval by authorities and utility operators; V2H and V2G (vehicle-to-grid)-capable Nissan Leafs have been deployed in Japan where concerns about energy security amid typhoons, cyclones and nuclear disasters have driven its approval, but its use is still sparse on a global scale.

The capability differs from "vehicle-to-load" introduced by Hyundai and Kia in the Ioniq 5 and EV6, enabling owners to plug directly to the vehicle's lithium-ion battery to power devices like kettles and lights when camping, or recharge batteries in electric bikes and power tools for example.

ELECTRIC VEHICLE NEWS

THE CHARGING FAMILY OF VOLKSWAGEN GROUP COMPONENTS: THE PROTOTYPE OF THE MOBILE CHARGING ROBOT, THE DC WALLBOX AND THE FLEXIBLE CHARGING STATION. SOURCE: VW

There was no immediate response to whether V2H capabilities for other EVs made by Volkswagen Group, such as the Audi e-tron, would be made available at the same time. In 2020, Audi also announced it would pursue bidirectional charging.

Topics discussed also included autonomous driving to the ability to "plug and charge" – a capability implemented on Australia's Tritium chargers, where payment for charging is done automatically when the car is plugged in.

Diess also offered an update on a 20,000 euro car, first promised for 2020 in 2018. "Price is a challenge. We are working on electric cars around 20k euros for entry segments," he said.

Diess said that another software upgrade would enable "plug and charge" in the ID.4 my mid-2022, as well as faster charging and "autohold" which maintains the pressure applied in braking to make stopping and starting in traffic a more pleasant experience.

"We will have a major OTA update for the ID.4 coming this summer, which will add features like Plug&Charge and AutoHold, as well as a higher capacity onboard charge capability," he wrote.

Diess also offered his view on using LiDAR for autonomous driving, something Tesla's Elon Musk has frequently said is too energy-intensive, going so far as call the use of light-emitting radar in self-driving technologies a "fool's errand" and that "anyone relying on lidar is doomed."

Volkswagen's deal with Argo AI has already spawned an all-electric Kombi that the company hopes will be put into service as robo-taxi.

Diess argues that although LiDAR is still pricey to implement, it offers "redundant perception" to full-surrounds cameras. "Lidar technology is still expensive, but todays the only way to offer redundant perception to the 360 camera systems which are a must," he wrote. "Safety is really crucial in autonomous driving. For level 3 driving you need redundant perception."

ELECTRIC VEHICLE NEWS

NSW ORDERS 79 MORE ELECTRIC BUSES FROM SYDNEY FACTORY

By Joshua S. Hill | 15 February 2022 | The Driven

ONE OF 6 CUSTOM DENNING ELEMENTS AT BUSWAYS PENRITH IN SYDNEY, SEEN AT PENRITH STATION. SOURCE: CUSTOM DENNING GROUP, FACEBOOK. IMAGE: OLI POATE

The New South Wales government is to commit another $70 million to its planned transition of the state's bus fleet to zero emissions technology, with a new order for 79 new electric buses to be built by Western Sydney-based company Custom Denning.

The plan to transition NSW's 8,000-strong bus fleet was first announced in 2019, and is expected to have an increase of 5-10% on the state's electricity demand.

The fleet is operated under contract by publicly and privately owned operators under 13 contracts servicing the Sydney metropolitan area. Premier Dominic Perrottet and NSW minister for transport and veterans David Elliott this week toured Custom Denning's factory in St Mary's. The 79 new buses are intended to operate in Sydney's inner west.

This new order also pushes the total number of electric buses ordered by Transport NSW from Custom Denning to 101. "The NSW Government's commitment to transition the entire 8,000-plus bus fleet is supercharging jobs and manufacturing in Western Sydney," said Elliott.

"Bus customers are already experiencing the benefits of electric buses from Penrith to Bondi, and we will continue to back local manufacturing.

Electric buses made by Custom Denning have been trialled around Sydney over the recent year, with the first operating in the Sydney suburb of Bondi earlier last year.

A second Custom Denning electric bus was spotted in operation late last year in Western Sydney, being trialed by Busways.

In June 2021, Volvo and TAFE announced a scheme to retrain motor mechanics in readiness for the transition to 100% electric buses.

ELECTRIC VEHICLE NEWS

THREE GLOBAL TRENDS THAT WILL IMPACT EV TRANSITION IN 2022

By Bridie Schmidt | 20 January 2022 | The Driven

SHANGHAI GIGAFACTORY 3 BODY SHOP. SOURCE: TESLA

The year 2022 promises to be a big one for electric cars, as countries push on to reduce carbon emissions on the path to net-zero by 2050.

Electric cars, and also hydrogen-powered vehicles to an extent, will play an important role in reducing transport sector emissions. According to the latest EV outlook report from BloombergNEF, 60% of new car sales worldwide must be electric by 2030 if a net-zero scenario is to be achieved.

To put that in perspective, that's approximately 40 million cars a year according to Statista – 40 times the EV production output of pioneering electric car maker Tesla in 2021.

And though Tesla is planning to increase its production capacity of both electric cars and battery cells to power them, it can't, and won't, be doing it alone.

European auto group Volkswagen AG, which holds VW, Audi, Porsche, Cupra, Seat, Lamborghini, Bentley, Ducati and Skoda under its umbrella, plans to sell 1 million EVs in 2021, and become the global market leader by 2025.

Other carmakers in Europe are also having to toe the line to meet strict emissions limits or face big fines (as VW did in 2020 after its ID.4 launch was delayed by software issues) – although, according to clean transport lobby group T&E, some are exploiting loopholes to delay the switch to clean transport.

Meanwhile in China, EV giants like BYD and the joint venture between General Motors, SAIC and Wuling have the Asian economic giant pushing 3 million units by the end of the year. We're likely to start seeing more budget electric cars from the likes of BYD and Great Wall Motors in Australia in 2022.

The continued spread of electric cars is certain, but there are a number of snags that could hold back record EV sales growth.

ELECTRIC VEHICLE NEWS

Global chip shortage and supply chain issues

The global semiconductor shortage and other supply chain issues have already seen carmakers adopt tactics to continue production amid a reduced supply of chips and parts needed to make cars.

Some simply cut production; according to JATO, the auto industry at large sold 2.4% less cars than in 2020 and 27% less than in 2019.

Others rejigged their vehicle mix to concentrate on larger vehicles that would yield higher returns per unit, which has also had the effect of ensuring they meet strict emissions limits in Europe by making more electric vehicles. Volkswagen for example halted production of its Golf for weeks at a time, as drivers turned increasingly to its range of SUVs, or to its recently introduced ID.3.

While the global chip shortage and other supply chain difficulties affect the wider auto market (and other industries for that matter), how carmakers can respond will determine how well they ride the crisis.

Tesla is a prime example of how to do this: instead of cutting production, it relied on its agile approach to software, securing chips from new suppliers and rewriting the code to integrate them with its electric cars. While the broader auto industry saw drops in sales, Tesla doubled its output from just shy of 500,000 units in 2020 to 936,000 in 2021.

The cost of battery materials as demand for resources heats up

Battery making costs are expected to fall below $US100/kWh by 2024 according to BloombergNEF, but the rising demand for the materials to make them could see a hiccough in reaching this magic number in 2022.

Lithium prices are already soaring, having skyrocketed some 540% since the start of 2021 – and they have "much further to run", says Credit Suisse analyst Saul Kavonic (via AFR).

Another material used in lithium-ion batteries, but one that does not hit headlines quite as much as lithium, cobalt and nickel, is graphite. A lithium-ion battery contains about 20-30% graphite, but there is a global shortage looming.

This shortage is the key reason interest in synthetic graphite producers like Australia's Novonix has increased in past months. With its ASX share prices up 342% in the past year and readying to list on the US Nasdaq stock exchange, the company – which is headed by battery scientist Chris Burns and counts Tesla lead battery researcher Jeff Dahn amongst its advisors – says it is currently the only supplier able to provide large volumes of synthetic graphite for use in battery anodes in the US.

How soon it can do that though is the question. On Thursday, it expanded upon its recent deal with multinational energy company Phillips 66 to make anodes in the US, inking a two year deal with an option to extend one extra year. With a production facility based in Chattanooga, Tennesee, it is eyeing 10,000 metric tons of the stuff per year by 2023.

In the meantime, battery makers are clambering to secure graphite supply – Tesla for example has just inked a deal with Australia's Syrah Resources for natural graphite from its Mozambique mines and processed in Lousiana, US.

ELECTRIC VEHICLE NEWS

Likewise, prices are on the up having increased 20-25% in the past year according to Stockhead, which also notes cobalt price increases of 11.5%.

Charging infrastructure rollout

Whilst many electric car owners are likely to be top them up at home overnight much like a mobile phone, that's not always possible or practical, and the rollout of charging infrastructure will continue to charge forwards in 2022.

But demand is already outstripping supply, says Tritium CEO Jane Hunter. And the ability to ramp up production to fill that demand is tied in with global supply chain and logistics issues.

The Australian-based company, which has an estimated 15-20% market share, has just listed on the tech-focused Nasdaq and has all shoulders to the grindstone to fill a massive $US82 million ($A113 million) backlog of orders.

Shipping delays have doubly impacted delivery times for the company. In December, Hunter told AFR that transit time had increased from 35 days to up to three months. Tritium has plans to build a factory in Tennessee or Texas by the end of 2022, but we don't see production ramping up there until 2023 at the earliest.

Article updated to correct Novonix production target from 2023 to 10,000 metric tons.

NSW GOVT TO FUND 1000 ULTRA FAST EV CHARGERS

By Giles Parkinson | 2 February 2022 | The Driven

The New South Wales government has opened the first, $35 million funding round for what it says will be the country's most extensive electric vehicle charging network.

The $35 million is part of a $171 million funding program over four years to help roll out 1,000 ultra-fast charging stations across the state, announced last September.

Treasurer Matt Kean, who drives a Tesla Model 3, says the NSW government will fund up to 50 per cent of the capital costs of the charging bays which will be rolloed out on key travel routes across the state "so drivers can put range anxiety in the rearview mirror."

NSW has already introduced the most generous EV rebates in the country, comprising a $3,000 rebate for the first 20,000 EVs priced under $68,750, and a stamp duty exemption for cars priced under $78,000.

The charging component was announced last year as part of its suite of initiatives that aims to reach a 50 per cent share of electric vehicles in new vehicle sales by 2030.

It aims to ensure that households in areas with limited off-street parking live no more than 5 km from an ultra-fast charger in metropolitan areas and no more than 100kms apart in regional areas.

ELECTRIC VEHICLE NEWS

The new funding round is the first of four funding rounds likely to take place over the next three to four years. The funding component can include the renewable energy generation and battery storage for EV charging stations. All charging stations must be powered by renewables, and on site battery storage is encouraged.

"This is expected to unlock around $160 million in private investment under our plan to build the biggest electric vehicle charging network in Australia," Kean said in a statement.

Construction is expected to start in the second half of 2022, with construction of all charging stations approved in this first round to be completed within two years.

There are likely to be four rounds over the next three to four years to construct at least 1,000 fast and ultra-fast chargers state-wide. Ultra-fast chargers can take as little as 15 minutes to charge up to 400km and each site will be required to provide four charging bays, two of them rated at 350kW and two rates at least 175kW.

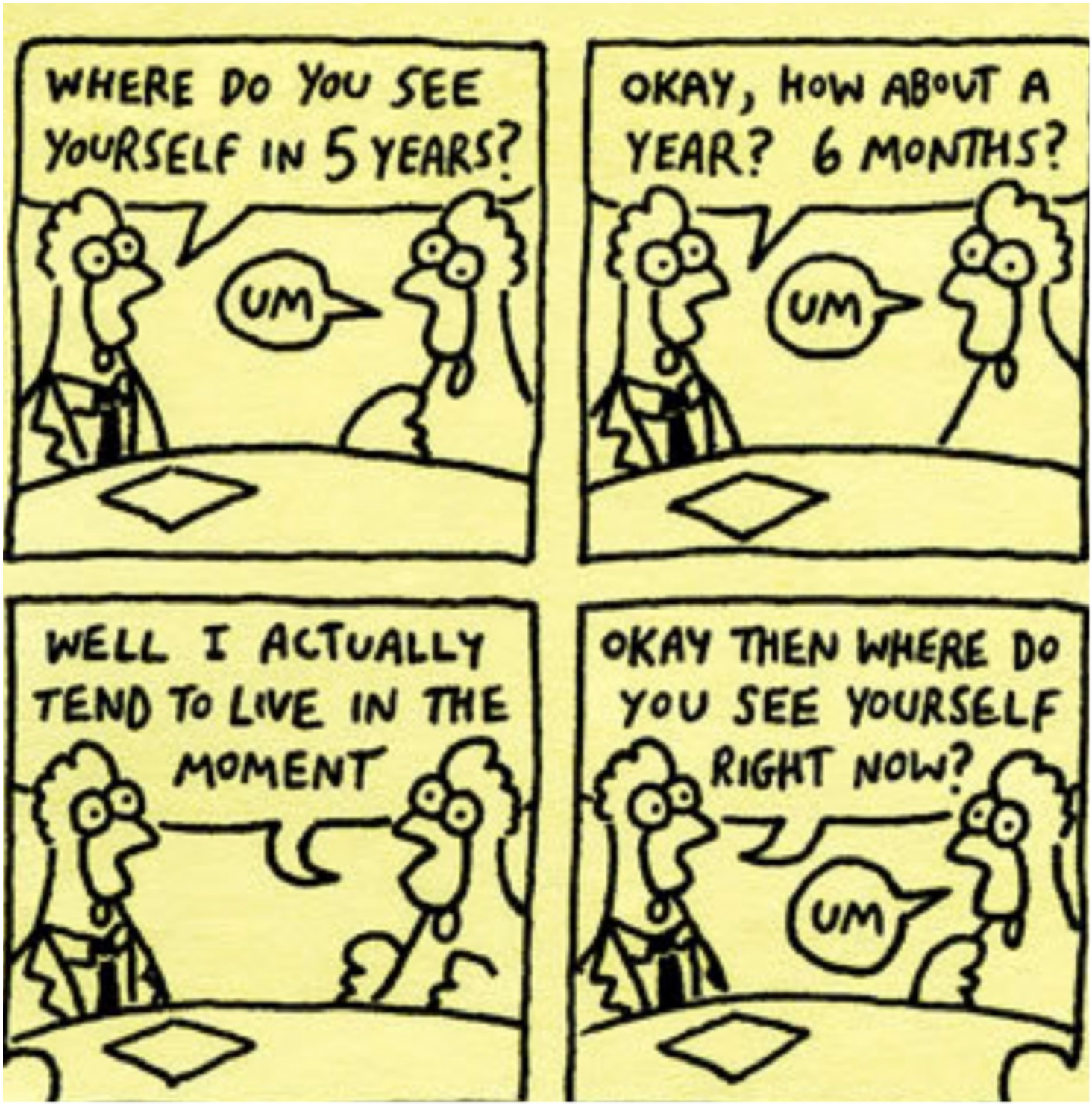
Applicants will be limited to $15 million of funding over multiple locations and a maximum of $490,000 per charging station (on average).

The NSW government ssays applications for co-funding will be assessed over two stages. Stage one will assess eligibility and high-level merit criteria, with a more detailed application for charging sites required in the second stage. Applicants will be limited to $15 million of funding over multiple locations.

It's expected the first stage applications will be finalised in April, with successful bidders and sites for funding to be announced in mid 2022.

HUMOUR BREAK

JOB INTERVIEW 101 FAIL



INTERNATIONAL NEWS

Infusing Technology into Apprenticeship Training

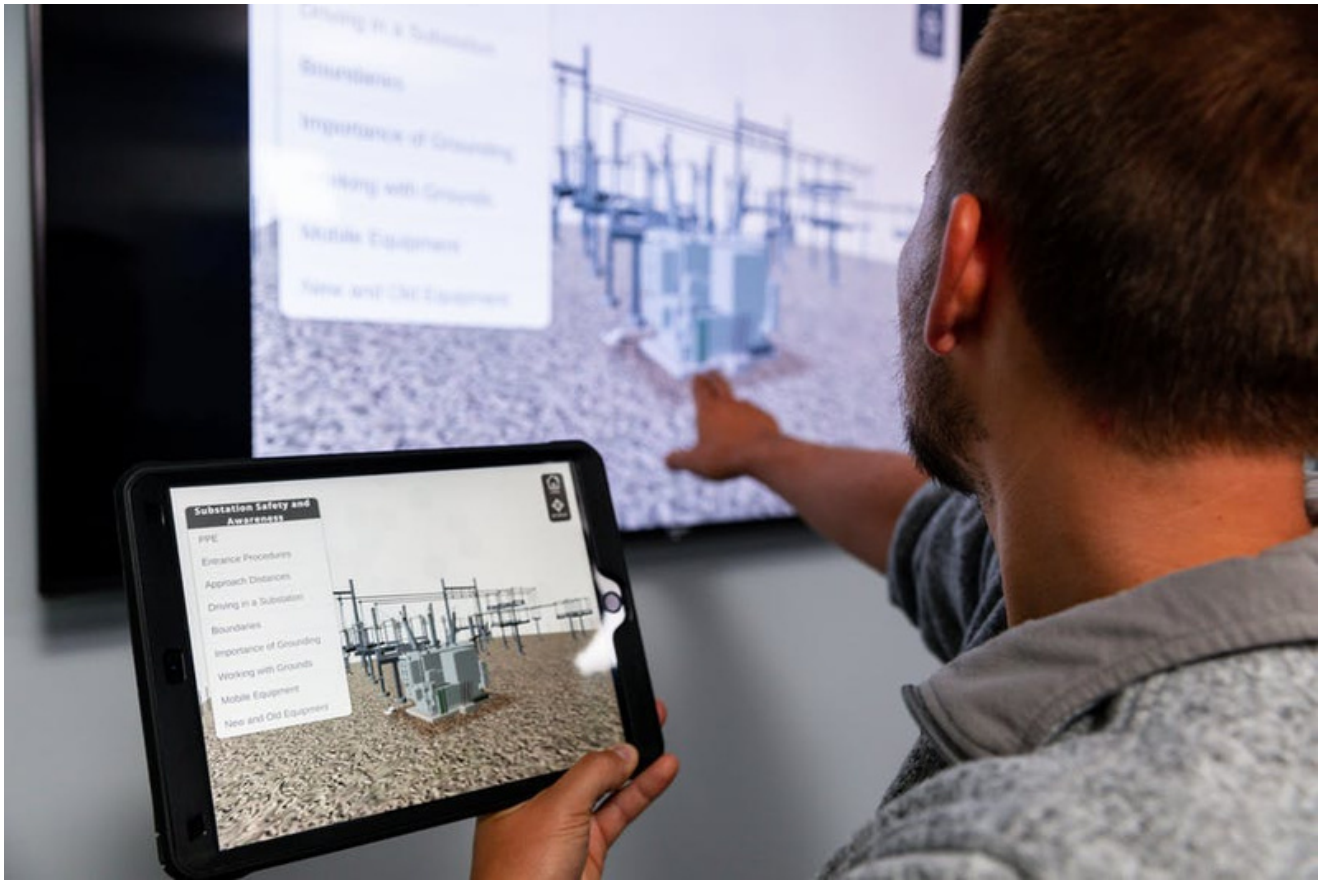
By Amy Fischbach | 16 February 2022 | T&D World

MidAmerican Energy rolled out a digital curriculum to supplement the training program for its substation workforce.

Not so long ago, apprentices could only learn skills and best practices through hands-on training. Today, apprentices can explore equipment within a substation anytime and anywhere through MidAmerican Energy's digital training curriculum.

Through a combination of animations, augmented reality (AR) and 3D modeling, apprentices can view components from any angle, visualize complex tasks and better understand how equipment works.

The curriculum also incorporates video demonstrations from other technicians and electricians across the company to supplement the apprenticeship content. While much of the apprenticeship is hands-on learning, the new digital curriculum can help bridge the gap when apprentices do not have the opportunity to work on those devices in the classroom or field.



A developer demonstrates a tablet-based substation safety and awareness app for substation technician apprentices.

INTERNATIONAL NEWS

Transitioning to Digital

Prior to implementing the digital curriculum and construction of MidAmerican's Training Center for Excellence in Des Moines, Iowa, continuing education for the journeymen was extremely limited, says Chelsea McCracken, vice president of safety, training and development at MidAmerican Energy. Supplemental training was limited to what could physically be lined up and worked on at any given place or time. Even then, the apprentice would have to travel to that location to experience what was being presented. MidAmerican Energy developed mock units for each work location and reviewed and shared text-heavy lessons-learned documents among groups.

Delivered via tablets assigned to each new worker, however, the new digital curriculum, developed in partnership with Index AR Solutions, will continue to be available for reference even after they top out as journeymen and help the next apprentices. With the new digital curriculum, MidAmerican's own personnel can fully capture these events and training opportunities on video and incorporate them into the appropriate section of the eBooks. This approach enables anyone to consume training content in a consistent manner, anywhere at any time.

Training Users

Imagery is used to reinforce Human Performance Improvement (HPI) concepts in substation technician apprenticeship digital training.

INTERNATIONAL NEWS

When rolling out the digital curriculum, it was essential to secure buy-in and engagement from everyone in the training process, McCracken says. This includes assigning a dedicated project leader, identifying subject matter experts early in the curriculum development process and helping represented workers understand their stake in the outcome. It is important for apprenticeship trainers and workers to understand how the material will be created and used, as their involvement is key to project success, she added.

After training is complete, workers can continue using their training tablets whenever they need to see an example of a device configuration or when they need refresher on a complicated procedure. Standards and safety rules are available and searchable on the devices, making them a convenient reference tool.

Investing in Mobile Technology

A worker discusses enclosed capacitor bank safety and maintenance for a video to be embedded in a training eBook.

INTERNATIONAL NEWS

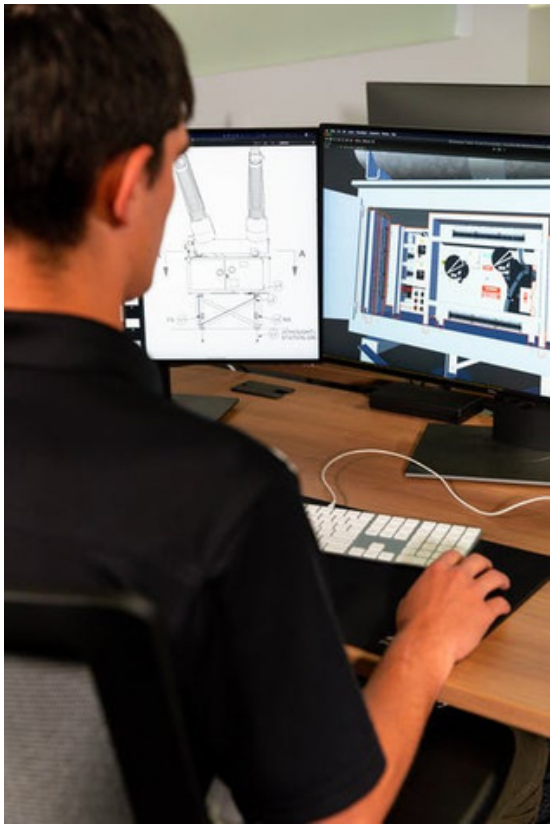
At MidAmerican Energy, substation technicians and electricians have a company-issued mobile phone and a company-issued laptop to perform their work-related tasks. As digital training content was being developed and after it was issued as final, company-issued tablets were used as the primary delivery mechanism. All final eBooks and mobile app visualizations are available on these managed company devices at each department location across the state.

On their first day, new substation technician and electrician apprentices receive a company-supplied tablet preloaded with the digital training material and supporting items such as standard manuals and safety rule books. Apprentices keep their tablets and use them as a field reference after training is completed. Electronic bookmarks and notes stay with each apprentice.

In addition, apprentices can access training eBooks on the company-issued mobile phones. MidAmerican also assigns technicians rugged devices for field work.

Training on the Go

MidAmerican Energy, which has 35 substation technicians, shifted from a four-year Substation Technician and Electrician apprenticeship to a three-year program.



A developer works on a mobile app that helps substation technician apprentices visualize substation components.

Condensing the apprenticeship into three years makes it essential that the training materials are high quality and accessible to technicians/electricians no matter where they are," McCracken says. The digital curriculum helps to train substation technician and electrician apprentices on the work they do in the field, as well as the laptops and other tools they rely on each day. This includes relay testing and troubleshooting, proper use of physical tools like multimeters and relay test sets, as well as "soft" tools like Human Performance Improvement (HPI) tools, safety rules and common practices such as setting up work boundaries.

The eBooks and apps comprising the digital curriculum provide apprentices a way to learn on their own using a familiar platform and a format that works best for them. The curriculum delivers information in a multi-modal fashion, using rich text, video and augmented visualizations that supplement the apprenticeship.

INTERNATIONAL NEWS

Advancing in the Apprenticeship

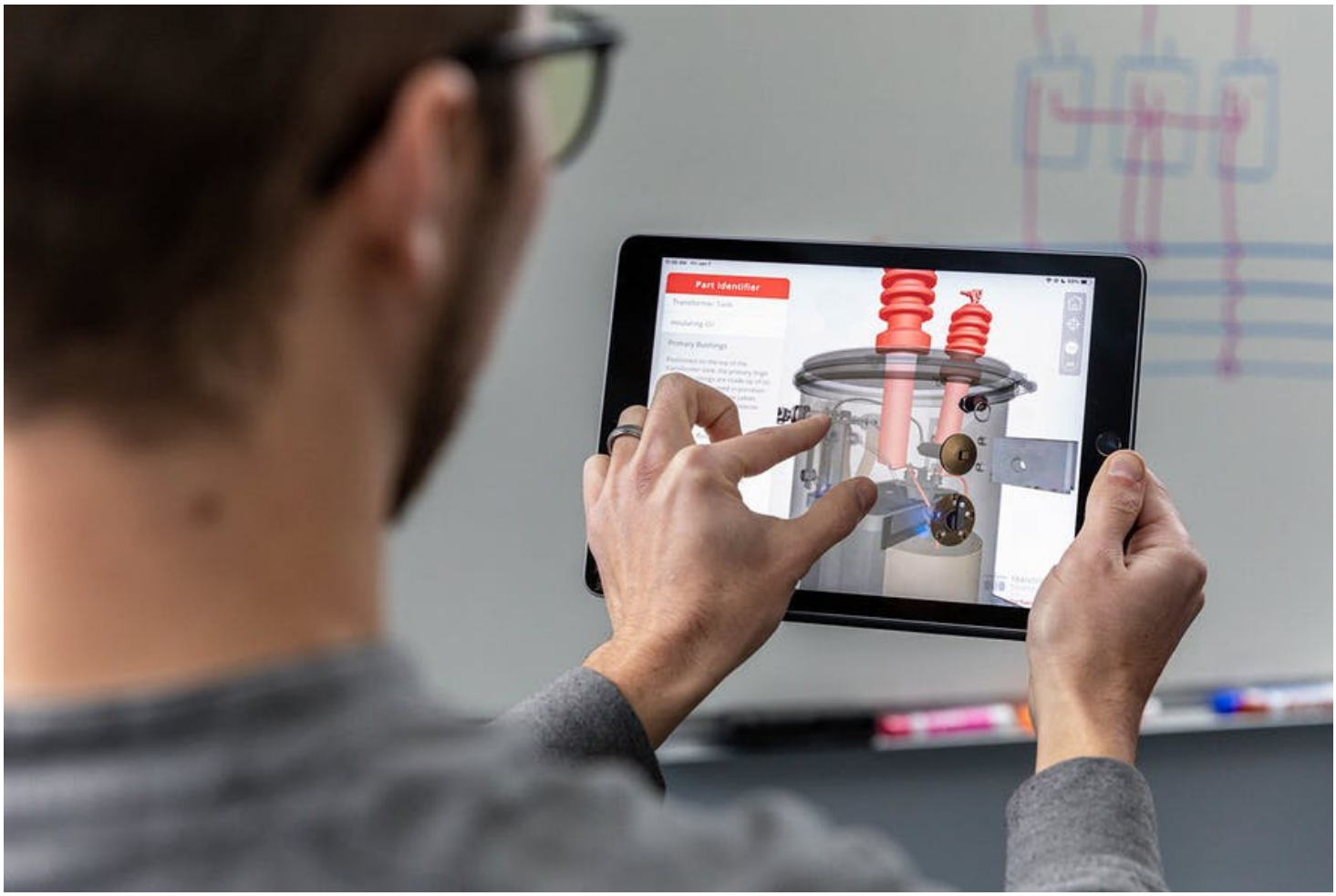
Videos ensure expert knowledge is captured and consistently shared.

Once the substation technician and electrician apprenticeship is underway, every six-month phase includes a 40-hour week at MidAmerican's Training Center for Excellence. Peer evaluations are given each month and reviewed by the Local Apprenticeship Committee via conference call. As an apprentice progresses through the training phases, they will use the tablet-based training elements to supplement and reinforce concepts learned in the Training Center for Excellence and better understand related material.

A Line Mechanic digital curriculum is currently in development. Once complete, line mechanic apprentices will use the curriculum in conjunction with NJATC materials for an immersive learning experience. Visualizations and training videos featuring subject matter experts complement written eBook instructions to show apprentices how to virtually wire transformers, understand how various types of equipment operate and more.

INTERNATIONAL NEWS

Taking a Hybrid Approach



Augmented visualizations help reinforce important concepts and boost knowledge retention.

The benefits of using a digital curriculum, which can help teams seamlessly transition from in-person training to virtual training, came into focus during the pandemic. MidAmerican apprenticeships that had deployed a digital curriculum were able to continue during work modifications necessary to respond to COVID-19 guidance from state and federal agencies with minimal impact to training schedules.

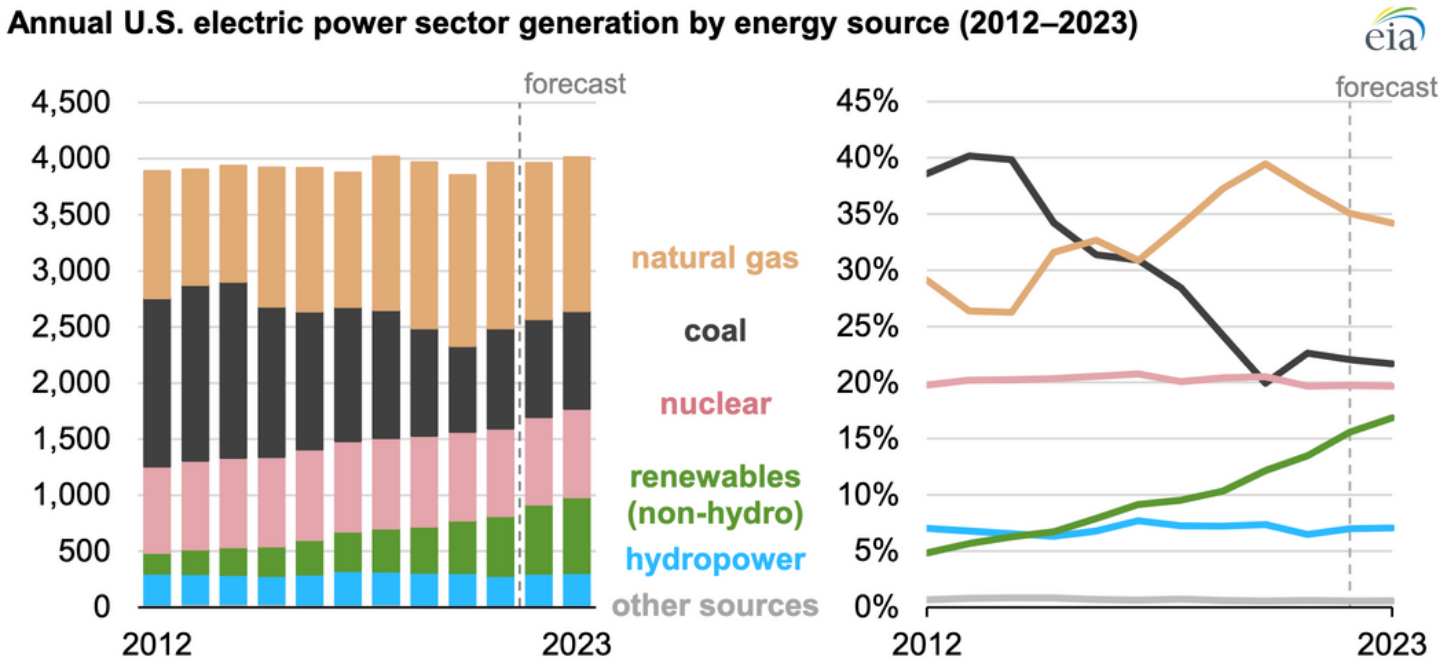
The recent global pandemic disrupted many business operations, particularly those requiring in-person gatherings. A mobile training platform can help minimize the impact of facility closures, prevent apprentices from falling behind and help ensure that staffing levels remain sufficient.

Hands-on and classroom training will continue to be a critically important component of MidAmerican apprenticeships, including those related to electric operations. The digital curriculum is a valuable supplement that helps reinforce concepts and procedures learned in the classroom using a device that can be taken anywhere.

INTERNATIONAL NEWS

New renewable power plants are reducing U.S. electricity generation from natural gas

By Tyler Hodge | 18 January 2022 | Today in Energy - US Energy Information Administration (IEA)



Source: U.S. Energy Information Administration, *Short-Term Energy Outlook*, January 2022

In our January *Short-Term Energy Outlook* (STEO), we forecast that rising electricity generation from renewable energy resources such as solar and wind will reduce generation from fossil fuel-fired power plants over the next two years. The forecast share of generation for U.S. non-hydropower renewable sources, including solar and wind, grows from 13% in 2021 to 17% in 2023. We forecast that the share of generation from natural gas will fall from 37% in 2021 to 34% by 2023 and the coal share will decline from 23% to 22%.

One of the most significant shifts in the mix of U.S. electricity generation over the past 10 years has been the rapid expansion of renewable energy resources, especially solar and wind. The amount of solar power generating capacity operated by the U.S. electric power sector at the end of 2021 is 20 times more than it was at the end of 2011, and U.S. wind power capacity is more than twice what it was 10 years ago.

Another significant shift in the generation mix has been a steady decline in the use of coal-fired power plants since their peak output in 2007 and the increasing use of natural gas, primarily as a result of sustained low natural gas prices. However, that trend reversed in 2021 when the cost of natural gas delivered to U.S. electric generators averaged $4.88 per million British thermal units, more than double the average cost in 2020. As a result, the share of generation from natural gas declined from 39% in 2020 to 37% last year, while the share of generation from coal rose for the first time since 2014 to average 23%.

INTERNATIONAL NEWS

In our current STEO, we forecast that most of the growth in U.S. electricity generation in 2022 and 2023 will come from new renewable energy sources. We estimate that the electric power sector had 63 gigawatts (GW) of existing solar power generating capacity operating at the end of 2021. We forecast solar capacity will grow by about 21 GW in 2022 and by 25 GW in 2023. We expect that 7 GW of wind generating capacity will be added in 2022 and another 4 GW in 2023. Operating wind capacity totaled 135 GW at the end of 2021.

Our forecast of growth in renewable electricity generation over the next two years leads to our forecast of a reduced need for fossil-fueled generation. Although we expect natural gas prices for electric generators to decline, the operating costs of renewable generators will continue to be generally lower than natural gas-fired units. We expect that regions of the country with the largest increases in renewable capacity, such as Texas and the Midwest/Central regions, will experience the largest reductions in natural gas generation.

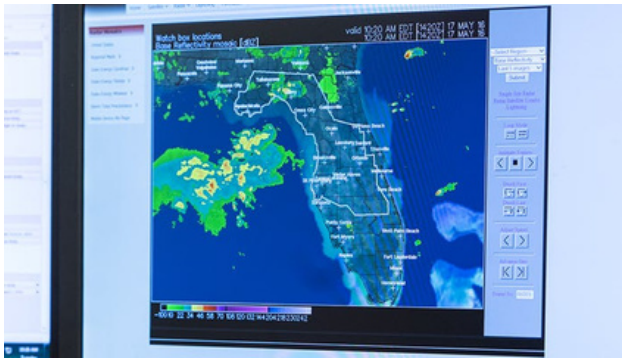
Duke Energy Florida Nets SAIDI Gains

By Barry Anderson and Brian Lloyd | 8 January 2022 | T&D World

Florida utility deals with thunderstorms with a new, multipronged strategy for operations centers, work crews and substation automation.

At a time when the climbing rate and duration of power outages in the United States is under growing scrutiny, it is important to look at success stories. People in the industry know that making big improvements on system average interruption duration index (SAIDI) is not an easy task and requires a detailed, multi-faceted plan.

Duke Energy is on pace to reduce its SAIDI by 20 minutes since 2018. This is not a simple thing to do when you are serving nearly 1.9 million customers in a region that experiences the most thunderstorms in the United States. To make this much progress in not much time, the utility implemented a multi-part strategy involving sophisticated sectionalizing of its distribution system, a restructuring of territory management, better repair process discipline, storm hardening, substation optimization and next-generation power grid planning.



The utility developed a hybrid mid-level command structure for the frequent thunderstorms that are common to Central Florida area. In this system, utility Meteorologists and operation centers collaborate to evaluate storm risk.

Duke Energy's power reliability team wanted to break out of the usual habits of a patchwork of repairs and the classic pole and cable replacement method of maintenance. Instead, the utility would attack entire sections of the grid — with a focus on those sections that are most demanding on labor and capital resources.

Duke Energy matured its strategy and approach to how it analyzes, plans and executes work around the substation. The utility refers to this as substation optimization, where the utility identified an entire area served by one substation and began hardening and improving assets, including feeders and circuits. The goal is not just better reliability and performance, but resiliency after storms. This is a way for Duke to focus efforts instead of being programmatic and spread out.

INTERNATIONAL NEWS

Focus on the Substation

An important concept underlying substation optimization is the focus on the substation as the "center of the universe." This involves making the appropriate investments into each of the feeders coming out of a particular substation. The strategy targets substations based on factors such as asset type, reliability improvement potential and capacity. Potential future use of distributed generation assets and electric vehicle saturation are also factors.

Duke's reliability team wanted to break out of the usual habits of a patchwork of repairs and the classic pole and cable replacement method of maintenance. Instead, the utility would attack entire sections of the grid.

Duke Energy asks the question, what should be done in an area served by a particular substation? The answer usually involves installing self-optimizing grid upgrades, storm hardening improvements with feeder hardening, lateral hardening either underground or on larger overhead poles with shorter spans. Another option might be replacing first-stage protective devices with auto-reclosing devices.

The substation optimization program is already underway, with Florida entering year one of the plan in 2021. This phase consisted mostly of planning, with twelve Florida substations chosen to undergo upgrades in 2022, with more substations entering the planning and design phase in 2023. The substation optimization program is still in its infancy, so it cannot be cited as a reason for the reliability improvements the utility has already measured but upgrading a dozen or so substations and working toward 25 substation upgrades each year is the utility's planned way forward and a path toward future reliability scores year after year.

INTERNATIONAL NEWS

Utilities can improve and deliver more reliable service by making sure our decisions are always anchored in making investments that provide a more disaster-hardened system.

All available data about a particular substation must be considered. For example, even weather and climate data are part of the strategy. Targeting sections of the grid that have been historically impacted by major storm events might offer some low-hanging fruit in terms of improving service reliability. In 2019 the company also used Exacter predictive analytics and circuit assessments to provide additional intelligence for where to channel resources. Exacter may be used going forward to assure quality installations and to further identify substation candidates for improvement. One of the largest customer benefits over time will be fewer outages and quicker restoration schedules thanks to substation optimization.

By strategically prioritizing the portions of the grid that have been most severely damaged by storms or are just perennial poor performers because of an aging infrastructure, the utility can free up resources to improve and maintain larger swaths of the grid. Much of the constraint to reliability improvement lies in those circuits that demand more service time and capital improvement.

Few other parts of the nation have more thunderstorm activity than Florida. In the western half of the peninsula in a typical year, there are over 80 days with thunder and lightning. Central Florida's frequency of summer thunderstorms equals that of the world's maximum thunderstorm areas: Lake Victoria region of equatorial Africa and the middle of the Amazon basin. So weather is perhaps the greatest opportunity for reliability improvement on which to focus.

INTERNATIONAL NEWS

Achieving Reliability Gains

According to Duke Energy, weather patterns are difficult to track, but the utility's methods are getting better with each new storm.

Deeper insights into circuit performance are important factors in Duke Energy's recent reliability gains. A reorganization of power grid responsibilities and restructured service territories means Duke Energy's four-section map is now a 12-section map, with each section having its own area director who is totally responsible for all aspects of their territory.

Now that there are 12 divisions, each with their own area director, there is someone responsible for reliability, customer satisfaction, response maintenance and capital improvements in those regions. This allows the utility to become more granular in its reliability measures as there is now more management intelligence in the command structure.

These leaders know their territories, where the pain points are, what technologies or tools can be helpful, and where to indicate to corporate for potential new capital investment.

Getting Disciplined

In addition to personnel and technology changes, Duke Energy is getting results from being disciplined in outage response time. Each field team and manager from each of the 12 sections needed to properly address feeder restoration, recloser restoration, overhead fuse restoration and underground fuse restoration.

In December 2018, reclosers in an outage-stricken area required 87 minutes to restore, but restoration time has since been cut by 12 minutes. In that same period, overhead fuse outages also saw a 12-minute improvement in restoration time.

In Duke's new strategy, storm impact frequency and severity can inform what infrastructure requires new capital expenditures, such as undergrounding.

The basic process on the ground by Duke Energy maintenance teams is now consistent and disciplined — designed to show continuous improvement. The mission is to put the feeders first and get on them quickly, using sectionalizing points and restoring them first instead of going off on a hunch and trying to find the source of an outage individually. Workers are encouraged to stick to the process.

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With the utility's newly assigned area directors, analytics and operations centers, Duke Energy gained visibility into the process. The outage mix will inevitably change over time, but the system can remain reliable on the factors operational teams can control, which includes response time. The discipline factor is keeping everyone in the loop on progress from the managers to the line workers doing the job, to central management teams.

Toward a Self-Healing Grid

From a technology and investment perspective Duke Energy Florida began connecting electronic reclosers across the grid in 2015 by devising what it called simple self-healing teams. This involves installing reclosers at the manual tie switch with communication between devices. When a fault occurred, Duke Energy could isolate and open up the midpoint, closing the recloser at the tie switch location and picking up the back half of the feeder from the back half of the adjacent circuit and vice versa. The approach is simple: Isolate and restore, and it has worked.

The next phase, which Duke Energy called the self-optimizing grid, began in 2018. It took the self-healing concept to the next level through further power grid sectionalizing. Before the transition to self-optimizing grid, a particular section might have around 2,000 customers, but now targets 400-customer segments. In this approach, Duke Energy targets installing electronic reclosers every 400 customers, 3 miles of line, or 2 MW of load.

When a fault occurs, grid operators can back-feed from multiple directions now that they can isolate and back-feed. This is not as simple as dividing of circuits and saturating the grid with reclosers. The utility also must be able to have connectivity and capacity. This requires creating new tie points. At this point, an intelligent network is created.

The result? Millions of customer minutes of interruption (CMI) saved through applying this technology. In 2020, Duke Energy saved 18.9 million CMI. In 2019, it saved 10.2 million CMI and another 13.7 million CMI were saved as of September 2021.

Improving Operations Centers

In grid operational centers, the data received by management is now structured to be "exception based." This includes asking questions like "What has changed?" "What is unusual?" "What is the delta?" "What should we focus our attention on and discuss to make improvements?" This has resulted in improvements to outage response times and restoration, but also in our internal processes and managed improvements.

Every morning at the 8:30 Daily Operations Call, if there are outages above certain CMI or outage length, operators call review an "exception 035 report," which is an outage management system (OMS) snapshot based on defined thresholds. The report includes information on outage duration, outage frequency and the number of customers affected. Anything over a set threshold triggers further action. Area directors talk to the line supervisor to find out what happened. Next come meetings on how to improve performance. These talks drive where capital improvement might happen in the areas that present the most frequent or severe issues.

The utility developed a hybrid mid-level command structure for the frequent thunderstorms that are common to Central Florida area. In this system, utility meteorologists and operation centers collaborate to evaluate storm risk and discuss where the most severe problems may take place in advance of the storm so the 12 operating areas can share and deploy

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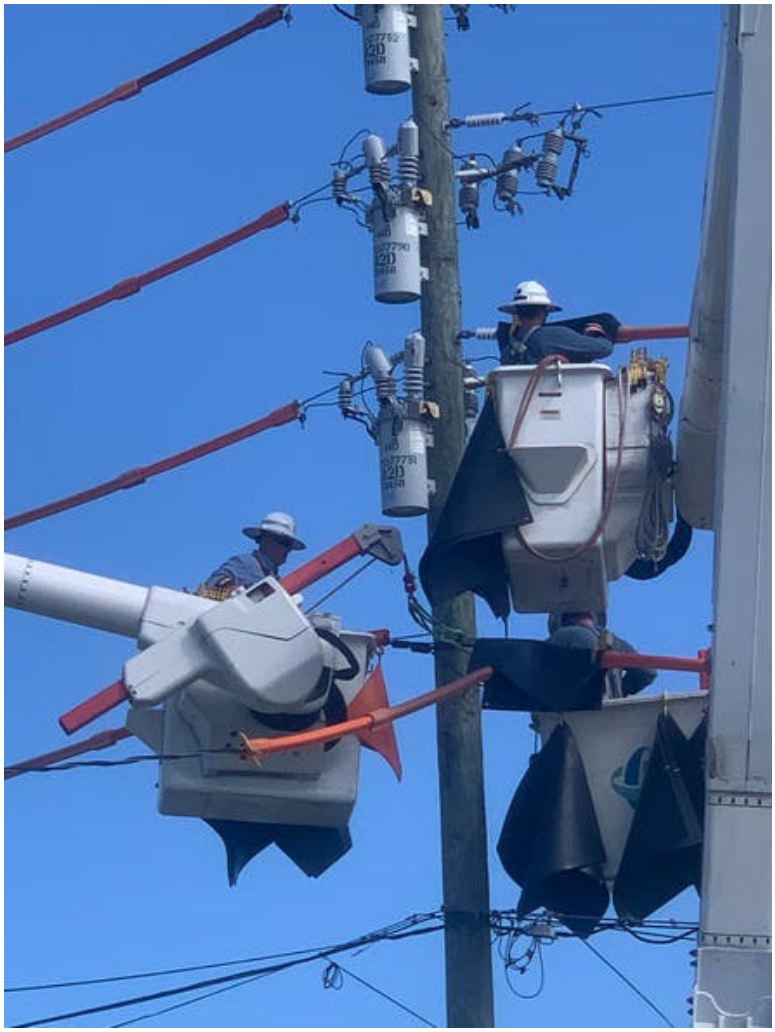
resources accordingly. Again, this requires the discipline to have discussions early in the day and prepare for what is to come.

Duke Energy meteorologists have developed some predictive weather event simulations specifically for severe thunderstorms. These are a work in progress as weather patterns are difficult to track, but the utility's methods are getting better with each new storm. An average Level 2 weather event, for example, is estimated to cause about of two SAIDI minutes, however some are more or less severe than anticipated.



Changing Needs for Power

Electricity users are more reliant on the product utilities sell than before, with so many working from home, or educating children at home. Utilities must ask whether they are making the right investments for customers who are relying on us more than ever before. Utility workers are keenly aware of the impact of lengthy outages to our customers.

Utilities can improve and deliver more reliable service by making sure decisions are always anchored in making investments that provide a more disaster-hardened system. For Duke Energy Florida, that means being extremely responsive to hurricanes and tropical storms and making sure that capital expenditures will be able to deliver quantifiable gains on these metrics.

Duke Energy wants to create a better customer experience, so it began studying data from customer feedback to address improvement opportunities. Duke Energy strives to create an environment for continuous improvement, which ultimately makes a better utility.

Barry Anderson is regional senior vice president, Customer Delivery, Florida, at Duke Energy. He is responsible for operations of the company's electric distribution system including construction, maintenance, engineering and resource and project management. He joined Duke Energy in October 2018 to serve in his current role. He brings more than 35 years of experience in the energy field.

Brian Lloyd is general manager of Region Major Projects at Duke Energy. His job responsibilities are asset management, project development, project management, filing management and business integration. His background includes analyzing trends for distribution equipment at Progress Energy, now a part of Duke Energy.

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Grid-Forming And The Next-Gen Grid

By Gene Wolf | 9 February 2022 | T & D World

Wind turbines, solar panels and batteries have a commonality.

The future is a fascinating subject. When it comes to digital technology, however, the crystal balls and Ouija boards are having a hard time keeping up with the latest developments. When it comes to the next-gen widget, it turns out predictions tend to be running behind what is actually happening. There are so many good candidates in the power grid that it's hard to pick one. There is, however, one grid element that has been getting a great deal of next-gen interest: energy storage.

More specifically, it's battery energy storage systems (BESS), which has a rather unique position when it comes to the grid. It's on the transmission system, distribution network, and behind-the-meter. It's also a critical element for making wind and solar more grid friendly. BESS are considered by some as renewable resource. So, there is a lot of speculation as to what can be expected for the next-gen BESS.

Without getting too technical, let's say these devices have one thing in common. They produce direct current electricity that needs to be converted into alternating current electricity for use on the power grid. That is done by using inverter-based technology, which is becoming a problem as their numbers increase.

There is a problem, however, these inverter-based devices are replacing massive rotating machines (e.g., generators and turbines). As a result, the grid is losing the inertia these generators produce. Inertia is a form of kinetic energy storage that comes from large synchronous (i.e., the rotation of the shaft is matched with the grid frequency) machines. This kinetic energy provides short term balance between the supply and the load. Before getting into that discussion, let's dig a little deeper into energy storage in general.

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Transformational Experiences
T&D World produced its first energy storage supplement in 2009. The technology was mostly pumped-storage and lead-acid batteries, and there was a lot of activity around renewables. When the second energy supplement came along almost a decade later, the changes were amazing. The emphasis had switched with energy storage becoming an integral part of more sophisticated applications. That's when BESS became part of distributed energy resources. It was a gamechanger and gave a hint of things to come.

By incorporating BESS technology on both sides of the meter, suppliers tapped into grid stabilization services. Grid resilience started trending, which opened new opportunities for BESS technology. It moved from a niche player to a major force on the power grid.

Interestingly, the 2009 supplement quoted a research organization predicting the global energy storage market would grow from around US$ 329 million in 2008 to more than US$ 4.1 billion by 2018. Well, it did! It actually grew beyond that prediction to about US$145 billion in 2018 according to a recent Fortune Business report. The report also expected the global market spending to reach US$ 211 billion by the end of 2026.

BESS applications are definitely a growth technology. It will continue based on the push for decarbonization with renewable resources. That brings us back to the concerns with electronics-based, inverter-based renewable resources. Fortunately the technology has been improving and there are advanced inverter applications available to address the issues.

Grid-Following vs Grid-Forming
An insight from the NREL (National Renewable Energy Laboratory) comes in the form of a publication saying, "Today's electric power systems are rapidly transitioning toward having increasing proportion of generation from nontraditional sources, such as wind and solar power, as well as energy storage devices." These resources are connected to the grid through grid-following inverters. That's another clue for where the next-gen energy storage is headed along with wind and solar renewables.

This is a good place to talk about inverter technologies. Grid-following inverters track the voltage angle of the grid to control their output. These grid-following inverters rely on the fact that the system voltage and frequency are stabilized by inertia (i.e., rotating masses) sources. BESS using grid-following inverters don't handle large grid disturbances well. They typically shut down until the disturbance has passed, and require the grid to reestablish after a blackout before reestablishing themselves.

As more large fossil-fueled generating plants are retired and replaced by renewables, the grid needs more stabilizing inertia sources. That is where grid-forming technology comes into play. Grid-forming inverter technology can establish grids and strengthen operating grids. It has an independent internal frequency reference, which allows grid-form inverters to form an island grid.

When grid-forming technology is paired with advanced automation and controls, it makes possible virtual synchronous machines. They can be used to provide services large grids need to operate with lots of renewables. This technological innovation is why grid-forming inverters are starting to generate interest and gain traction for next-gen status.

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John Glassmire, senior advisor for Hitachi Energy's Grid Edge Solutions, provided some actual experience with grid-forming technology including virtual synchronous machines in the real world on the Australian transmission grid. Glassmire reports, "Most battery energy storage deployed globally offers partial network stability, but the next generation of battery energy storage – particularly energy storage that uses grid-forming energy storage with virtual synchronous machine technology – is critical for enabling renewables to fully displace fossil-based synchronous technology."

Glassmire continued, "For example, Australia pulls 24% of its electricity from renewables, a huge accomplishment for a country of this size. Australia is continually progressing toward net zero emissions, but the output of these renewables are variable. As the installed wind and solar capacities grow, there is a need for new integration technologies. As part of Australia's commitment to renewables, Hitachi Energy took part in Australia's Energy Storage for Commercial Renewable Integration, South Australia (ESCRI-SA) project by providing a large-scale grid-edge solution leveraging microgrid technology."

According to Glassmire, "Hitachi Energy supplied a 30MW BESS on the lower end of the Yorke Peninsula in 2018 on a long radial feeder. The ESCRI-SA BESS is a grid-forming system built on Hitachi's virtual synchronous generator platform, which strengthens the grid by providing inertia, high fault current, and fast power injection, as well as competitive market services. The Hitachi system is also capable of seamlessly transitioning into island operation when faults occur on the upstream feeder. The island power supply comes from the nearby 91 MW Wattle Point windfarm and distributed solar."

Before leaving the ESCRI-SA project, Glassmire pointed out, "The virtual synchronous machine offers an extremely valuable service to the grid. It mimics the behavior of old school technologies like synchronous machines and synchronous condensers, but entirely through power electronics. They can even mimic more sophisticated and newer devices like a STATCOM that stabilize grids with benefit of also providing energy and ancillary services. A BESS with a grid-forming inverter including a virtual synchronous machine is a different animal from one with a grid-following inverter system. The automation and controls are a key element to using grid-forming inverters in large utility grids"

Growing Interest

Late last year, another grid-forming project was announced in Australia. The Australian utility AGL broke ground on the Torrens Island 250MW/250MWh grid-forming BESS project in November 2021. The battery will be supplied by Wärtsilä with over 100 grid-form inverters supplied by SMA. AGL expects the battery to be fully operational in early 2023. AGL said the BESS is designed to be increased to 1,000MWh in the future. They expect the BESS to take part in Australia's National Electricity Market.

With the expanding interest in grid-forming technology the U.S. Department of Energy (DOE) announced it is providing funding for the US$25 million public-private Universal Interoperability for Grid-Forming Inverters (UNIFI) Consortium. DOE said, "The Consortium brings together leading researchers, industry stakeholders, utilities, and system operators to advance grid-forming technologies." The Consortium will be led by NREL (National Renewable Energy Laboratory), EPRI (Electric Power Research Institute), and the University of Washington.

One of major tasks of the Consortium is the development of standards for the hardware needed for these next-gen inverter-based technologies. Interoperability is a key concern for any emerging technology. We have seen in the past that new technologies must play well with each other if they are to be accepted by the power delivery system. That is the reason so many manufacturers such as, Danfoss, Eaton, General Electric, Hitachi Energy, Schneider Electric, Siemens Energy, SMA, and others are interested in the UNIFI project.

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The next-gen of inverter-based BESS is here and just in time considering what's happening. The penetration of wind, solar, and BESS resources is increasing and causing concern by those responsible for a stable grid. When these three resources exceed 60% or more of the online generation capacity operators get nervous. The old-school inverter-based technology can't provide the inertia needed to generation and load stability of massive rotating machines.

Grid-forming inverters, however, are available to address these concerns, which are happening more often than might be expected. It's all about adding virtual inertia in a world where clean energy replaces fossil-fuel massive rotating machines. In this case, the next-gen grid-forming BESS is here today!

Recycled Lithium-Ion Batteries Can Perform Better Than New Ones

By Jordan Wilkerson | 1 February 2022 | Scientific American

A novel method of recycling such batteries could help meet skyrocketing demand.

Lithium-ion battery modules for electric vehicles sit on the production line at a car manufacturing plant in Dingolfing, Germany. Credit: Krisztian Bocsi/Bloomberg via Getty Images

Lithium-ion batteries are at the heart of nearly every electric vehicle, laptop and smartphone, and they are essential to storing renewable energy in the face of the climate emergency. But all of the world's current mining operations cannot extract enough lithium and other key minerals to meet skyrocketing demand for these batteries. Establishing new mines is an expensive, years-long effort. And mining also creates a host of environmental headaches—such as depleting local water resources and polluting the nearby region with runoff debris—that have led to protests against new mines.

All of this means the ability to recycle existing batteries is crucial for sustainably shifting the global energy system. But recycling lithium-ion batteries has only recently made commercial inroads. Battery manufacturers have hesitated over concerns that recycled products may be lower in quality than those built from newly mined minerals, potentially leading to shorter battery life or damage to the battery's innards. Consequences could be serious, particularly in an application such as an electric vehicle.

But new research published in Joule has hit upon what experts describe as a more elegant recycling method that refurbishes the cathode—the carefully crafted crystal that is the lithium-ion battery's most expensive component and key

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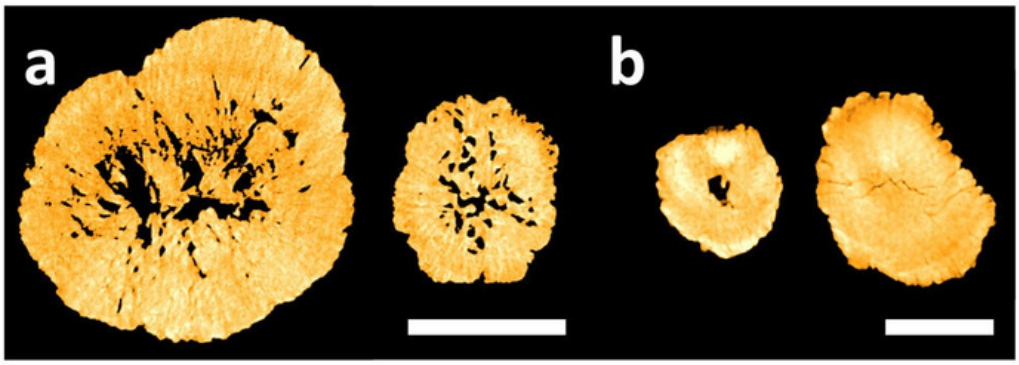
to supplying the proper voltage. The researchers found that batteries they made with their new cathode-recycling technique perform just as well as those with a cathode made from scratch. In fact, batteries with the recycled cathode both last longer and charge faster. The team's approach and successful demonstration are "very unique and very impressive," says Kang Xu, an electrochemist at the U.S. Army Research Laboratory, who was not involved in the study.

A JOKE NO MORE

Yan Wang, a materials science professor at Worcester Polytechnic Institute and co-author of the new study, started researching battery recycling 11 years ago. At the time, he says, "some people joked with me, 'There's not enough batteries for you to recycle.'" That joke is not aging well. The Department of Energy estimates the battery market may grow 10-fold over the next decade. To ease the market's growing pains, "recycling of lithium-ion batteries—getting that material back into the supply chain—is critical," says Dave Howell, director of the DOE's Vehicle Technologies Office. The DOE funded the new research as part of its massive effort to spur large-scale battery recycling innovations in the U.S.

When a lithium-ion battery is providing power, a cluster of lithium ions moves from one crystalline "cage" (the anode) to another (the cathode). The most common methods currently used to recycle these batteries involve dismantling and shredding the whole battery, then either melting it all down or dissolving it in acid. The result is a black mass—with a texture can that can vary from powder to goo—from which chemical elements or simple compounds can be salvaged. Those recovered products can then go through the same commercial manufacturing process that newly mined elements do to make cathodes.



Cross sections of the recycled cathode particles (A) and particles made from new materials (B), taken with an X-ray microscope. The scale bar is 10 micrometers in (A) and 5 micrometers in (B). Credit: "Recycled cathode materials enabled superior performance for lithium-ion batteries," by Xiaotu Ma, et al., in Joule, Vol. 5, No. 11; Nov. 17, 2021 DOI:https://doi.org/10.1016/j.joule.2021.09.005

Wang and his colleagues use a very similar process—but instead of completely breaking the battery down to its constituent chemical elements, their technique keeps some of the old cathode's crucial composition intact. After they shred the battery, they physically remove the less expensive bits (such as the electronic circuits and steel battery casing) and recycle them separately. What is left is mainly the cathode material; they dissolve this in acid and then remove impurities. Next, they carefully add just a touch of fresh elements that compose the cathode, such as nickel and cobalt, to ensure the ratio of ingredients is just right—another distinction from common recycling methods. After a few more steps, the result is an effectively refreshed cathode powder, composed of tiny crystalline particles that can be stuck onto a metal strip and placed in a "new" battery.

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\Because a cathode is crafted from a precise mix of precious minerals to achieve the battery's specific voltage, slight changes to its structure or composition can compromise its performance. Thus, much of the cathode powder's value is "in how you've engineered the particles [of powder] in the first place," says Emma Kendrick, a professor of energy materials at England's University of Birmingham, who was not involved in the new study. That value is lost if the entire battery is simply melted down or dissolved in one fell swoop, as in current recycling methods.

MORE PORES, FASTER CHARGE

Wang and his colleagues compared the particles in their recycled cathode powder with those in commercially manufactured cathode powder (largely made from newly mined minerals). They found that the recycled powder particles were more porous, with particularly large voids in the center of each one. These characteristics provide room for the cathode crystal to swell slightly as lithium ions squeeze into it, and this wiggle room keeps the crystal from cracking as easily as cathodes built from scratch. Such cracking is a major cause of battery degradation over time.
More pores also mean more exposed surface area, where the chemical reactions that are necessary to charge the battery can happen—and this is why Wang's recycled batteries charge faster than their commercially manufactured counterparts. A future ambition could be to design all cathodes to have this superior structure rather than just those made from recycled stuff, Wang says.

The latest findings demonstrate that "the cathode they can make is as good as—or even better than—the commercial material that we've been importing," says Linda Gaines, a transportation analyst at Argonne National Laboratory and chief scientist at ReCell Center, an organization that studies and promotes battery recycling. (Gaines was not involved in the new study.) Such imports largely come from China, which leads the world in battery recycling. But this situation means materials must be shuffled across the globe to be recycled, increasing the carbon footprint of recycled batteries and diminishing their allure as a more sustainable path. The approach developed by Wang's team cuts out a significant chunk of international trade and transportation requirements, carving a potential path for other countries to bolster domestic battery recycling. The process is currently being scaled up by Ascend Elements, formerly Battery Resourcers, a recycling company Wang co-founded.

Bushings Technology Review

28 January 2022 | INMR

This edited overview combines an edited contribution to INMR by retired Prof. Stanislaw Gubanski of Chalmers University of technology in Sweden with excerpts from issues of INMR.

Bushings are devices that allow conductors to pass through the earthed walls of transformers, switchgear and substation structures. An integral part of this function involves meeting all the electrical, thermal and mechanical requirements of the application. For example, bushings must provide reliable electrical insulation both internally (against breakdown) and externally (against flashover) of the conductor exposed to the rated voltage and also to periodic service overvoltages – even under contaminated conditions. Another key requirement is providing the mechanical strength needed to support the conductor as well as all external connections, including under short circuit and possible seismic forces. Moreover, a bushing must have the proper thermal design to avoid overheating of any of its components and prevent onset of ageing phenomena in its insulation – both at rated current and during short circuit events.

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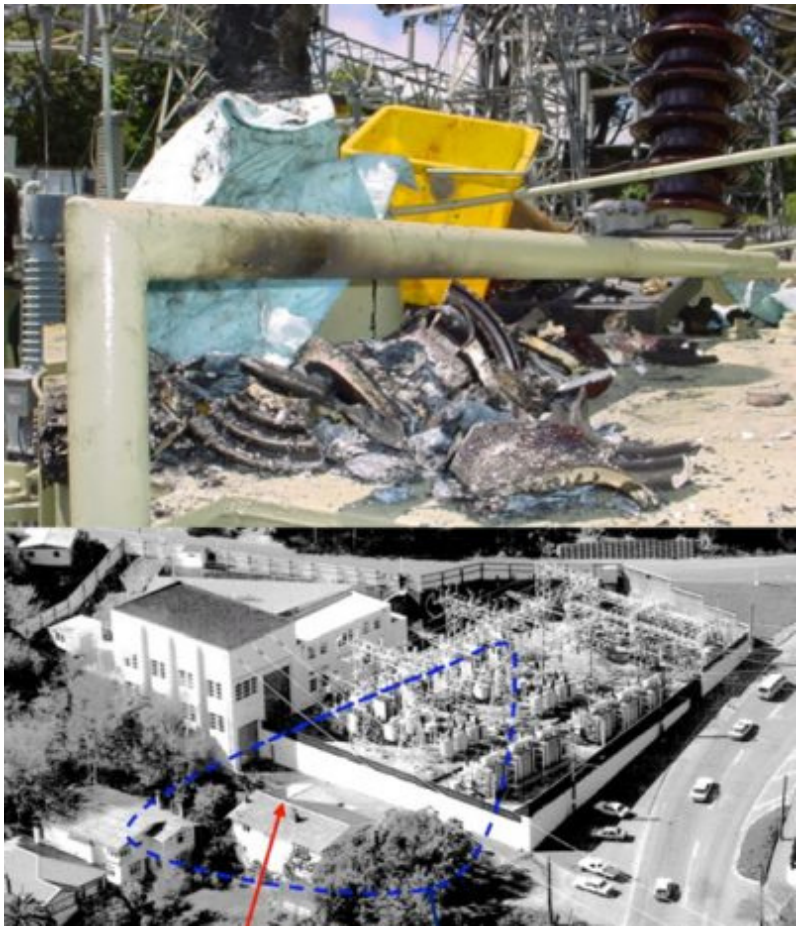
This edited overview combines an edited contribution to INMR by retired Prof. Stanislaw Gubanski of Chalmers University of Technology in Sweden with excerpts from issues of INMR.

Like a surge arrester, a bushing is a relatively low cost component ensuring the safe operation of a high value asset. While bushings account for only about 5% of the cost of a power transformer, their catastrophic failure can lead to total loss of the transformer and possibly other expensive equipment as well. Certain types of bushings can threaten not only substation personnel but even nearby communities.



Explosion of this OIP bushing in New Zealand launched porcelain shrapnel over wide adjoining residential area (dotted blue boundary).

Catastrophic bushing failure means expensive repairs or even total loss of transformer.

In their early years, bushings were little more than hollow porcelains filled with transformer oil or solid resin surrounding the conductor. Such simple bulk and solid type bushings are in fact still being applied at medium voltage levels. But as networks have become more sophisticated, the need was recognized to better distribute the electric field generated across a bushing – especially at higher voltages. This resulted in designs that were capacitance-graded. The basic principle was to distribute the natural field between conductor and earthed flange by employing intermediate conductive layers radially (to lower the field at the conductor and better utilize the insulation material) and also axially (to allow for higher flashover voltage values for a given arcing distance).

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Originally, materials used in the cylinders wound around the conductor included resin-bonded paper and carbon materials. These were later modified to designs involving less conductive grades of paper along with aluminum foil. One of the motivations behind development of field-graded bushings was reducing the diameters required for the porcelain housings. On ungraded bushings, electric field tends to be concentrated around the flanges and therefore risk of breakdown becomes high. On fine-graded bushings, stress is linearized and spread over more distance, resulting in greater safety margin. For example, the porcelain housing diameter on a simple 110 kV field-graded bushing is about 240 mm measured across the sheds. But to handle the same stress, an identical ungraded bushing would need a housing of almost double that diameter. The benefits of narrower external diameter translate into lower cost for the housing, reduced weight, less oil and less clearance diameter of the embedded shielding in the lower part.

The basic principle in bushing design consists of a conductor surrounded by an insulating solid cylinder that is mechanically fixed to the earthed barrier. As discussed, distribution of electric field inside such a construction, is highly non-uniform in terms of both axial and radial components. The highest stress concentration appears at the so-called 'triple junction' between the earthed wall, the insulating cylinder and the gaseous or liquid medium outside the bushing body. This localized high concentration of stress can trigger the onset of partial discharges, sometimes referred to as 'gliding discharges' since they have a strong capacitive coupling to the bushing's internal conductor and therefore proceed along the insulating cylinder's surface. They can lead to tracking along the bushing and even result in flashover. Initiation of gliding discharges as well as their subsequent development becomes easier when the unit capacitance of the insulation (i.e. across its thickness) is greater. Therefore, the voltage level for their ignition and propagation (virtually equal to flashover voltage) is determined by this parameter. This stands in contrast to other types of discharges, where the typical controlling parameter is electrode separation distance.

Given these considerations, the best way to increase a bushing's flashover withstand voltage is by improving electric field distribution along its surface. In the case of higher voltages, the most effective means to achieve this is through capacitive control for AC applications and resistive control for DC applications. Capacitive control is based on inserting metallic screens into the solid insulation of the bushing, essentially forming a system of in-series connected capacitors whose magnitude depends on geometric arrangement. Perhaps the most frequently used and effective solution is when series capacitances are maintained at equal levels. Fig. 1 illustrates the impact of modifying field distribution this way.

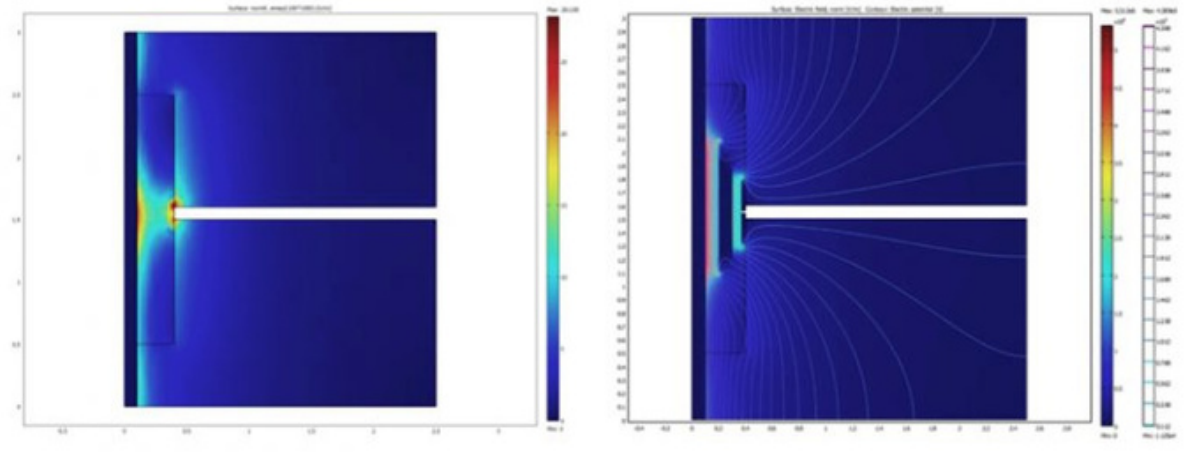

Fig. 1: Comparative electric field distribution in bushing without (left) and with field controlling capacitive screens.

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Inserting metallic screens during manufacture of a bushing used to be demanding and labor-intensive but modern core winding equipment has made it highly automated. In the case of paper insulated bushings, metallic foils are inserted between the different paper layers. Choosing the appropriate radius and length of these screens allows for the desired series capacitance. Optimal resistive control of electric field distribution in the case of DC bushings usually involves covering the critical region near the electrode with semi-conducting layers. The aim here is to increase resistance with increasing distance from the earthed electrode.

Alternative Bushing Technologies

In the case of bushings for higher system voltages, there have traditionally been three main types of insulation system used: oil-impregnated paper (OIP), resin bonded paper (RBP) and resin-impregnated paper (RIP). New resin-impregnated synthetic (RIS) types, without oil, have also been developed and are finding growing application.

Dry RIS type bushings installed in China at 66 kV and 110 kV.

OIP Bushings

Since the main insulation of substation transformers has been based on oil-impregnated paper, this same insulation philosophy has carried over and become the most commonly used technology for constructing bushings. In fact, it is estimated that up to two-thirds or more of all installations of a bushing on a power transformer involve an OIP design. In certain markets, such as China and the United States, this proportion is probably even higher. This market preference for OIP style bushings has been maintained over the years due to a variety of refinements made by some of the leading manufacturers. These improvements have allowed the technology to remain attractive both to intermediate bushing customers (i.e. transformer OEMs) and also to final users, in spite of changing needs and requirements. For example, some bushing suppliers offer standardized high creepage porcelains on all OIP bushings they sell. The goal was to allow the same bushing design to be used across a variety of service environments and thereby reduce the need for end users to stock many styles of replacement units. It has allowed bushing manufacturers to streamline their own ordering and inventorying of porcelain to reduce unit cost as well as production lead times.

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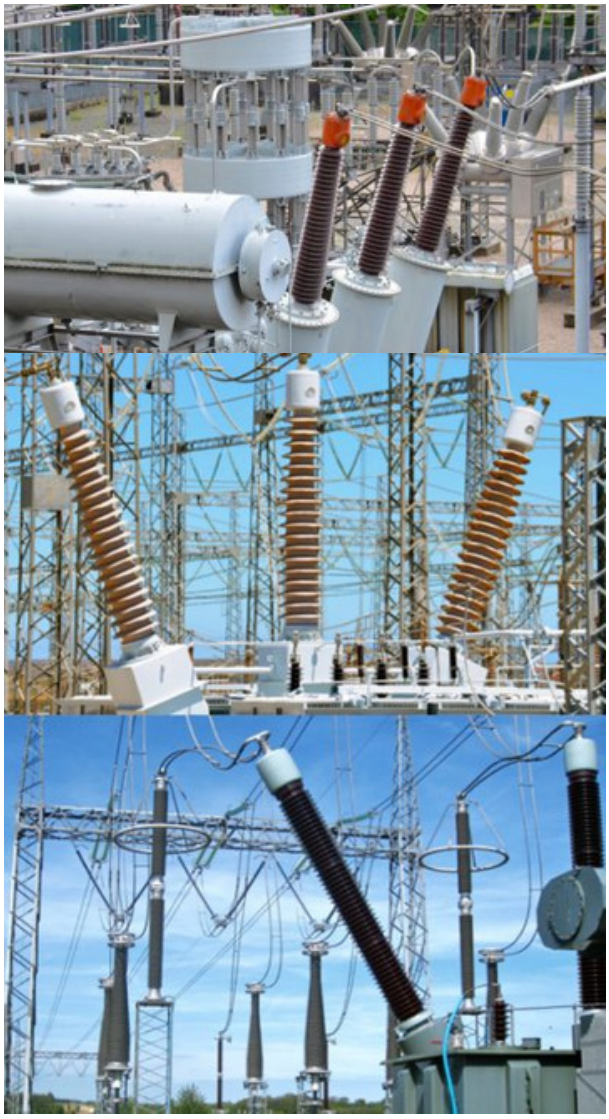

OIP types account for majority of all bushing installations on transformers.

Similarly, over the years OIP bushing suppliers have made design changes aimed at reducing the diameters of porcelain housings to make them slimmer and lighter. This has suited transformer manufacturers who prefer bushings that are easier to handle during transport and installation. Slimmer profiles have offered benefits apart from reduced weight: firstly, the porcelains themselves carry lower cost since decreased diameter significantly reduces purchase price; secondly, slimmer designs mean the volume of oil within bushings could be correspondingly reduced. With this has come progressively less concern about risk of leaks and fires.

Optimizing OIP design has allowed reduced diameters of external porcelain housings.

Apart from these types of design changes on an industry-wide basis, various individual OIP bushing suppliers have made additional improvements: better methods to seal against leaks; designs to facilitate horizontal or vertical mounting; better visual monitoring of oil levels; easier interchangeability between transformer and switchgear applications; and better mechanical contacts between top terminal and conductor to avoid the potential for heating should the conventional threaded contact weaken. Other refinements have also been developed that allow OIP bushings to be changed out quickly in the field with minimal impact on operation of affected apparatus. Due to competitive forces, these innovations have been matched by others in the industry with the result that most suppliers offer improved versions of OIP technology.

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Among subtle improvements in OIP bushings has been improved sight glass design for visual monitoring oil level.

One of the areas within this technology where there could be growing interest for further development is improved condition monitoring. There are hundreds of thousands if not millions of OIP units operating worldwide and one question is how intelligent such a design should be, especially in regard to internal monitoring of oil level and other service parameters. Still, given the many refinements made to these designs over the years, it seems unlikely more can be done to enhance performance and functionality or further reduce cost. Indeed, this style of bushing has reached a state of design maturity with limited room for further optimization.

Resin Bonded Paper (RBP) Bushings

Manufacturing RBP bushings has been based on winding layers of resin-coated paper around the conductor under heat and pressure to laminate the layers together. This process is inherently difficult to control and therefore such designs have suffered relatively large numbers of failures over the years due to voids and other defects. In spite of this drawback, however, the RBP bushing style has found a market because of price. Presently, use is limited mainly to lower voltage levels since risk of thermal instability and even runaway due to dielectric losses in the paper is comparatively high. For this same reason, operating radial stress in such designs is usually maintained at around 2 kV/mm, lower than for other bushing types.

Resin-Impregnated Paper Bushings

Compared with RBP bushings, significant improvements have been achieved by introducing a technology whereby the paper insulation is impregnated with epoxy resin and then cured. The resulting insulation system, containing field grading elements, is dry and void free. This technology involves higher material as well as product costs but offers benefits such as being non-combustible, providing an impregnable seal for the transformer tank, being easily machined to required dimensions and remaining unaffected by ambient humidity. Moreover, when equipped with a composite housing, there is no risk of explosive shattering. Great care, however, has to be taken during the curing cycle to avoid internal stresses and formation of cracks – especially as volumes of material increase for high voltages. Typical radial operating stress in RIP bushings is around 3 kV/mm.

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RIP bushings in Canada, China and Belgium.

RIP bushings have no dynamic processes occurring within their cores and therefore offer long service lives. Other advantages include eliminating any risk of leaks or explosive failure of an oil-filled component. Over the years, incidents of exploded OIP bushings resulted from excessive operating temperatures when cooling systems failed on transformers operating at 100% load. Even if not leading to an explosion, situations such as this can still shorten the effective service life of an OIP bushing to as little as 10 years. While a normal OIP bushing can operate well up to 105°C, an RIP style can deal with temperatures greater than 120°C. Indeed, testing by suppliers has confirmed that thermal ratings for RIP bushings are considerably higher than for OIP equivalents. This superior thermal behaviour is an advantage in utility markets where transformers are being run at high load.

Apart from thermal advantages, RIP bushing technology is viewed as the way forward simply because it offers a dry solution. In spite of successive refinements made to OIP designs, their most important drawback remains because it revolves around the presence of oil. Typical problems have included leaks due to worn out seals, excessive filling of reservoirs in horizontal mount applications or unusually high operating temperatures. These types of bushings also suffer from greater vulnerability to lightning strike or other factors that can trigger explosive failure. Similarly, moisture ingress presents a constant and potentially severe problem. Finally, in the case of connection to SF6, presence of oil is undesirable due to the consequences of leaks. All these drawbacks favour a dry bushing technology such as RIP. Indeed,

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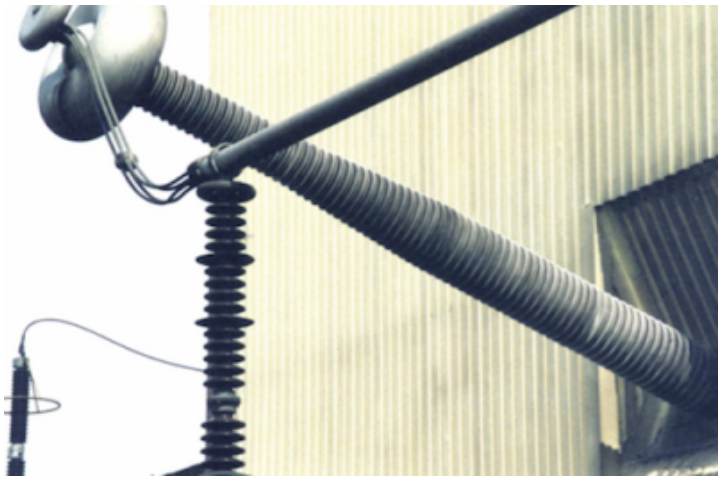
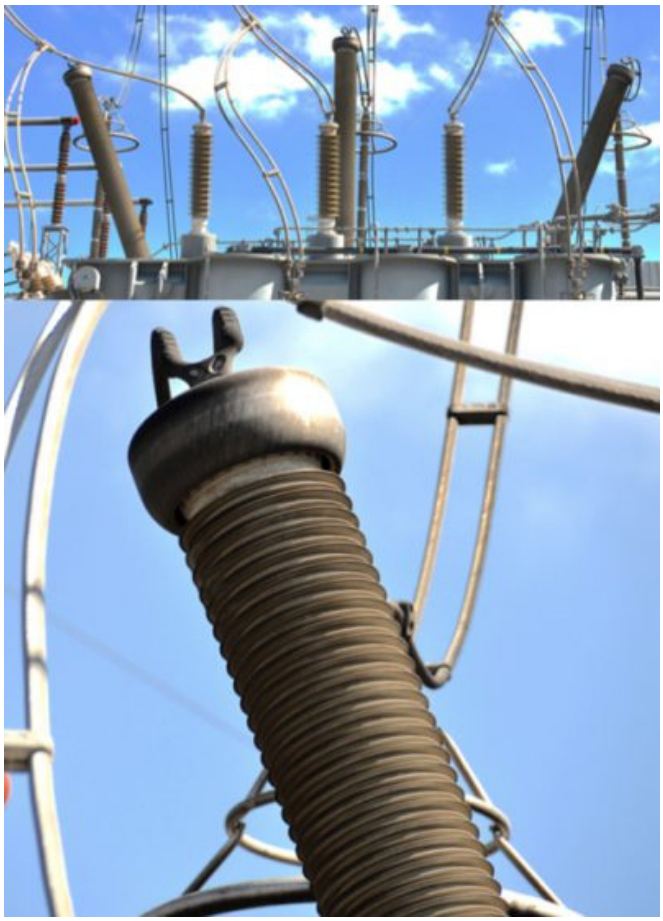
there seems an accumulating trend toward dry bushings that is reflected in a steady rise in its share of the total graded bushings business. Further increases are expected due to application-specific advantages of RIP technology. For example, the OIP design for oil-to-gas connections is cumbersome and difficult to maintain while the RIP alternative is a comparatively easy technical solution. RIP technology also offers important advantages in the area of oil-to-gas and oil-to-oil applications.

As with OIP technology, suppliers of RIP bushings have sought to incorporate product refinements to justify the higher price normally associated with this technology. Among the most important developments in this regard has been application of silicone housings in place of the porcelain that still dominates OIP bushing installations. This technical solution is viewed as the ultimate in bushing design and performance. There is no doubt that market acceptance of silicone housings on a bushing has been far greater for RIP than for OIP designs to the extent that probably more than 90 per cent of all graded bushings that are silicone-housed have RIP cores. This is because the real advantages of silicone material are most evident to customers when applied to this technology and in some respects even help RIP better compete against OIP styles. Germany, Switzerland and Austria are examples of markets where dry bushing technology incorporating silicone housings is widely accepted due to safety and environmental concerns.



Uneven pollution distribution on porcelain-housed wall bushing makes it more vulnerable to flashover under wetting.



Uneven pollution layer on silicone-housed RIP bushing at 400 kV substation in South Africa.

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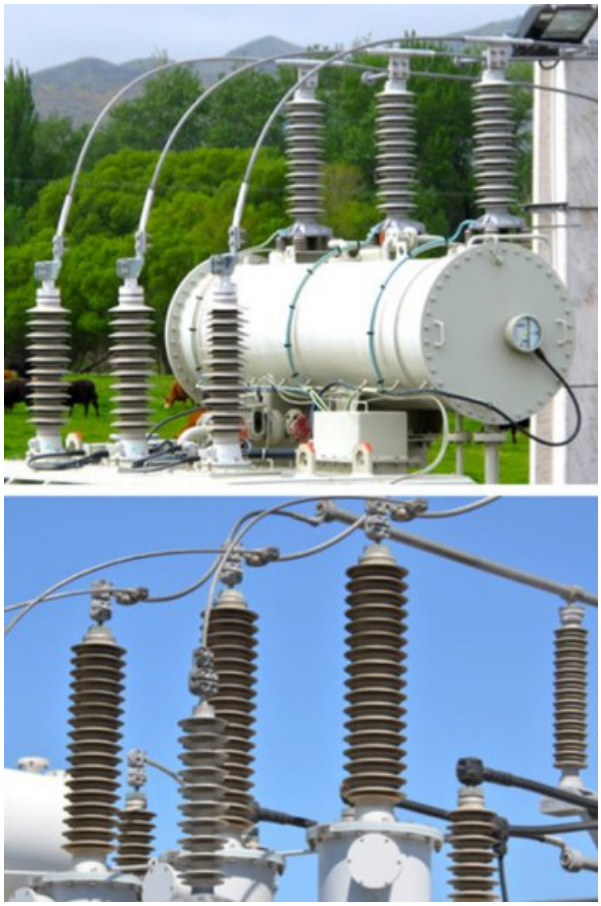
The motivation behind transition to silicone in place of porcelain as a housing for bushings has involved factors such as reduced risk to people and apparatus, better pollution performance, easier handling and faster production lead times. Bushings can be especially sensitive to pollution since they are often inclined or located under roofs – situations that can lead to uneven deposition of contaminants. A bushing then becomes more vulnerable to flashover and in such cases silicone is preferred to porcelain. Other application conditions can also make a bushing more vulnerable to pollution and favour a silicone housing over one made of porcelain. However, one of the challenges in replacing porcelain with silicone on an RIP bushing has been cost, especially at voltages below 245 kV where much of the volume is focused.

Slimmer diameters of RIP units compared to most OIP designs have also meant that the porcelain shells being replaced are less costly, only accentuating the price difference. An early problem when it came to changeover of external insulation away from porcelain was that the new silicone insulators were often specified as a one-for-one replacement for porcelain. This meant that the larger flanges required for porcelain were also specified for the composite alternative, even though not strictly necessary. This has become less an issue since bushing suppliers and users have both grown to understand the need to optimize the entire design. Moreover, the growing level of standardization in this industry has resulted in sizes and diameters of fittings becoming more uniform.



Polymeric-housed bushings in New Zealand and South Africa.

Among the notable developments when it comes to application of silicone housings to dry bushings – both RIP & RIS styles – has been a process that sees sheds molded directly onto the cured core. This technology has been available for many years and is best suited up to a maximum voltage. The principal advantage is cost reduction because direct molding eliminates need for the FRP tube as well as the dielectric material that fills the space between core and tube. Notwithstanding cost advantages, application of direct molding onto RIP cores has not achieved widespread use. Apart from the investment needed by the bushing manufacturer to be able to implement this process in-house, there are technical issues, especially at higher voltages. For example, there must be an extremely good chemical bond between core and silicone to avoid any possibility of interface problems. There is also the issue of 'cold switch-on behavior'. When silicone rubber has been molded directly onto the RIP core, vapor will likely have migrated through the material before energization and could be absorbed by the resin body. This could mean that, at least initially, the bushing will have a higher dissipation factor.

Another potential drawback of direct molding relates to mechanical function. If the mechanical requirements of the bushing exceed those of its RIP core and conductor, the added mechanical strength of a tube will be necessary to help carry the load. A tube also offers the benefit of providing a barrier against moisture. In this regard, it may not be appropriate to draw a parallel between mold-on silicone bushings and experience with polymeric arresters that have

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experienced growing use of direct mold technology. Arresters are not intended to last 30 to 50 years and, if they fail, it is often not a serious problem. If a bushing fails, the whole transformer is in trouble.

Apart from external insulation, there do not appear any major developments in the way RIP cores are produced that might significantly reduce cost. Drying and curing cycles are critical steps and cannot easily be shortened. Nor has the resin that forms the body of the RIP bushing changed significantly. Indeed, rather than looking at changes in the resin body itself, suppliers have typically looked for optimized production logistics. The entire process for manufacturing these bushings is technically demanding, particularly as voltage levels climb, and this has limited the number of qualified suppliers. Whatever practical refinements are still to be made to RIP bushing technology will likely be in such areas as better grading of the condenser layers to make them progressively smaller and more efficient. There may also be improved process control to improve robustness of manufacturing, making it a more repeatable process that results in a consistent product every time. A void the size of a pin hole can result in an entire RIP core being relegated to the scrap heap. There is no possibility to recycle the material since it is a thermoset resin that cannot subsequently be melted down.

Damage to bushing core due to fast transients.

In the end, a purely technical comparison between OIP and RIP bushing technologies may not be the decisive factor in customer preference. Given the role of commercial considerations in purchase decisions, success will go to bushing suppliers who offer the most features for the price, irrespective of technology. These include creepage distance, seismic capability, cantilever strength and total interchangeability for application on transformers or breakers, among others. Similarly, not everyone in the industry is convinced that RIP is always the better choice. This technology comes with disadvantages that must also be considered – from higher price to greater uncertainty about how the core is ageing. This is because, unlike the case for OIP styles, reliable ageing analysis on an RIP bushing cannot be performed in the field. Rather, the unit has to be removed from service and returned to a laboratory for testing. Given the power utility environment, there will always be concerns about how bushings are ageing. For this reason, some predict that the tendency for new bushing types may be more oriented toward gas-filled or gas-impregnated units in place of those relying on organic dielectrics.

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Other Designs & Considerations

Gas-insulated bushings with composite housings in Belgium, Czech Republic and Korea.

In contrast to longstanding OIP, RBP and RIP bushing technologies, more and more designs today make use of pressurized gas, predominantly SF6, as internal insulation. Metallic screens are used for controlling electric field stress inside the bushing body. As discussed, selection of the external housing of the main insulation in a bushing is one of the key factors affecting service performance and cost. For indoor applications with low contamination and normal humidity, resin-based RIP solutions do not require an additional housing over the epoxy core. This is not the case, however, for either OIP or gas-filled bushings, both of which require porcelain shells or composite insulators. For safety considerations, application of the composite solution is often preferred when considering a gas-insulated unit under high internal pressure.

Another way to categorize bushing technologies available today relates not to commonalities in design and construction but rather to main areas of application or applicable voltage levels. Probably the most common application of bushings is on power transformers, where the outer parts operate in air, other gas or oil. OIP bushings are currently available up to 1200 kV while capacitance-graded bushings with epoxy resin impregnated insulation have been developed up to 1000 kV. Apart from UHV, another specialty application includes high current bushings (i.e. with operating currents up to 40 kA) used on the low voltage side of transformers and also in generators. One of the key design requirements here is capability to effectively dissipate heat.

Another broad group of bushing applications involves connections to gas-insulated switchgear (GIS), most typically as entrance bushings. RIP based condenser cores embedded inside a porcelain housing or composite tubes with silicone sheds both function well in this regard. For the gas part, a discharge resistant surface varnish is necessary to fulfill the requirement of resisting corrosive by-products from decomposition of SF6. In addition, requirements for direct connection between transformer and GIS are becoming increasingly common and special designs of oil-to-gas bushings have been developed for this purpose.

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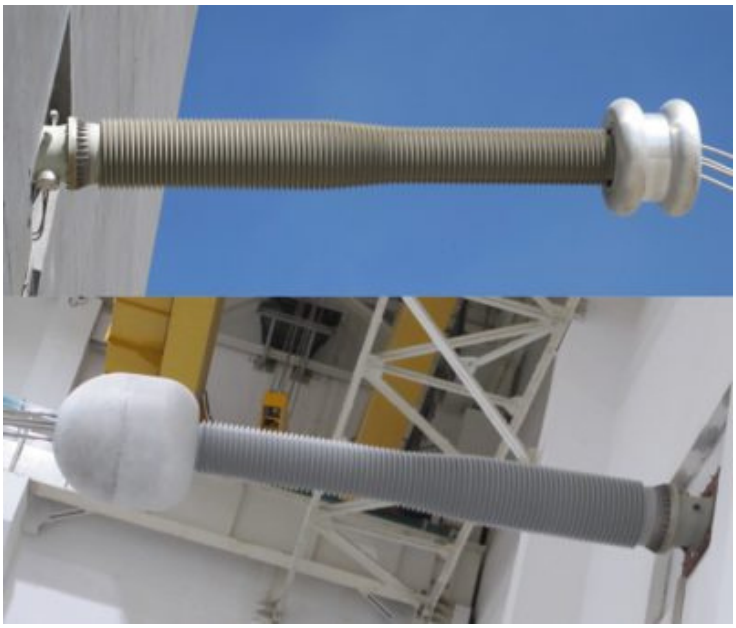

Dry RIP wall bushings with composite housings increasingly preferred at HVDC converter stations.

Transformer bushings at HVDC substation.

Yet another growing application – especially in countries such as China, India, Brazil, South Africa, Norway and Canada, among others – relates to HVDC converter stations. Nowadays, manufacturers offer special bushings for connecting to HVDC transformers, reactors or air-insulated system components up to ± 800 kV DC and higher. These can operate in a transformer oil environment, indoors or for any outdoor connections. As discussed, in contrast to high voltage AC applications, the performance of an HVDC bushing is influenced by the resistive properties of its materials and therefore stress control must be appropriately adjusted. For example, it is important to control the field in the oil part of an OIP HVDC bushing since the ratio between resistivity of paper and that of oil can be as high as 104. Use of composite insulators in the design of bushing shells for the highest voltage levels provides not only superior flashover performance but also high mechanical withstand. Another issue relates to the dynamics of charging under DC. This remains an important factor to take into account – not only during testing but also in terms of impact on flashover performance, especially during voltage reversals. Yet another factor to consider in UHV bushing applications relates to better understanding ageing of polymeric materials in such an environment.

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Failure of porcelain-housed equipment during earthquake.

The tendency towards increased transmission voltage levels and the resulting growth in dimensions of bushings has also made it necessary to better control parameters such as seismic behavior. Historically, several methods have been used to verify seismic capabilities of bushings. These involve static calculations to estimate the forces generated during a seismic event with a given ground acceleration and then comparing this against design capabilities of the equipment. Although IEEE and IEC standards involving shake tables have been used to qualify equipment for seismic areas, past earthquakes indicate that transformers and bushings that passed these tests can still sustain significant damage. To overcome this deficiency, numerical simulations have been developed and refined.

Conclusions

Development in bushing technologies has been impressive if not always obvious. Bushings today might look much like those of the past but there have been subtle refinements and improvements in scale, functionality, performance and cost. Among the driving forces behind this progress have been ongoing efforts by the industry to reduce costs as well as production lead times and standardize bushings to reduce need for users to stock many different types of spares. Moreover, internal competition between OIP and RIP styles has also pushed suppliers to seek optimization in both designs.

Another driver in development of bushing technology, especially in recent years, has included growing use of HVDC based transmission as well as increases in UHV AC voltage levels. At the same time, environmental demands for developing oil-free as well as low or SF6-free high voltage substations are creating new design challenges for the industry. Today, manufacturers have developed and already offer bushings for voltage levels exceeding 1000 kV and for high rated currents. On the HVDC side, work on developing ±1000 kV bushings has progressed.
RIP bushing technology seems well understood and this allows production of partial discharge-free condenser bodies, even for extremely large units. Increased use of new gas compositions (e.g. N2/SF6) in GIL will require elaborating new design criteria. Finally, growing application of silicone housings in bushing designs has created the need to further study their long-term behavior – especially under combined DC voltage, thermal and mechanical stresses.

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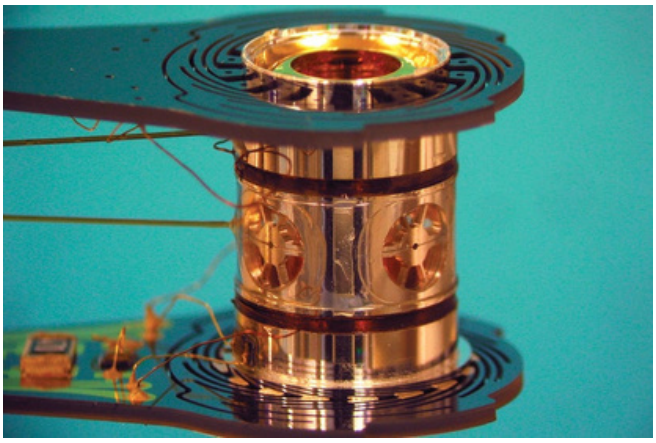
U.S. Project Reaches Major Milestone toward Practical Fusion Power

By Philip Ball | 2 Feburary 2022 | Scientific American

In a world first, the National Ignition Facility has generated a "burning plasma," a fusion reaction on the cusp of being self-sustaining.



Metallic case called a hohlraum holds the fuel capsule for National Ignition Facility experiments. Target handling systems precisely position the target and freeze it to cryogenic temperatures (18 kelvins, or –427 degrees Fahrenheit) so that a fusion reaction is more easily achieved. Credit: Lawrence Livermore National Laboratory (CC BY-NC-SA 4.0)

Nuclear fusion could potentially provide abundant, safe energy without the significant production of greenhouse gas emissions or nuclear waste. But it has remained frustratingly elusive as a practical technology for decades. An important milestone toward that goal has now been passed: a fusion reaction that derives most of its heat from its nuclear reactions themselves rather than the energy pumped into the fuel from outside.

A team at the National Ignition Facility (NIF) at Lawrence Livermore National Laboratory (LLNL) in California has reported this so-called burning plasma condition using an approach called inertial-confinement fusion, where the ferociously high temperatures and pressures needed to initiate fusion in a fuel of hydrogen isotopes are produced by intense pulses of laser light. The researchers' findings appear in Nature, with companion papers published in Nature Physics and on the preprint repository arXiv.org. "The data clearly show that they have reached that condition," says fusion physicist George Tynan of the University of California, San Diego, who was not involved in the work.

"The NIF results are a really big deal," says fusion physicist Peter Norreys of the University of Oxford, who was not part of the studies. "They show that the pursuit of an inertial fusion reactor is a realistic possibility for the future and not built upon difficult and insurmountable physics." Plasma physicist Kate Lancaster of the University of York in England, who was also not involved in the research, agrees. "This is an incredible achievement, which is a culmination of a decade of careful, incremental research," she says.

Nuclear fusion, the process that fuels stars and that is triggered explosively in hydrogen bombs, requires extreme heat and pressure to give atoms enough energy to overcome the electrostatic repulsion between their positively charged nuclei so that they can fuse and release energy. The usual fuel for producing controlled fusion in reactors consists of a mix of the heavy hydrogen isotopes deuterium and tritium, which may unite to make helium. The energy this releases can be harnessed for electricity generation—for example, by using the heat to drive conventional power turbines. Unlike nuclear fission—the process used in all nuclear power plants today—fusion does not use or generate large quantities of long-lived radioactive materials. And in contrast to fission, fusion does not involve a chain reaction, which makes it inherently safer: any changes to the working conditions of a fusion reactor will cause it to automatically shut down in an instant.

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Fission's advantage is that it typically occurs in reactors at temperatures of a little more than 1,000 kelvins, whereas deuterium-tritium (D-T) fusion starts at temperatures of around 100 million kelvins—hotter than the heart of the sun. Handling such a seething plasma is, to put it mildly, immensely challenging. One approach is to confine it with magnetic fields into a doughnut shape inside a chamber called a tokamak. This is the method of choice for many fusion projects, including the International Thermonuclear Experimental Reactor (ITER). for which a global collaboration is building a massive experimental reactor in France that is slated to achieve sustained fusion no earlier than 2035.

Inertial fusion does not try to trap the plasma but instead relies on inertia alone to hold it together for a brief instant after fusion is triggered by an ultrafast compression of the fuel. That creates a very brief outburst of energy—a tiny thermonuclear explosion—before the burning fuel expands and dissipates its heat. "Fusion energy schemes based on inertial confinement involve repeating the pulsed process over and over again, much like the pistons in an internal combustion engine, firing several times per second to give nearly continuous power," says Omar Hurricane of LLNL, chief scientist for the NIF's Inertial Confinement Fusion program, who was a team leader for the latest experiments.

Although inertial-confinement fusion does not have to solve the problem of maintaining a hot, wobbly plasma inside a tokamak, it does require tremendous inputs of energy to trigger the fusion process. The NIF team used 192 high-power lasers, all focused into a chamber called a hohlraum that is about the size and shape of a pencil's eraser and contains the fuel capsule of deuterium and tritium. The laser energy heats and vaporizes the capsule's outer layer, blowing it away and creating a recoil that compresses and heats the fuel in the center. In the NIF method, the laser beams do not directly spark detonation but instead strike the hohlraum's inner surface, unleashing a furious bath of capsule-compressing x-rays within the tiny chamber.

Researchers demonstrated the feasibility of starting fusion this way back in the 1970s. But getting to the burning-plasma point has been a slow process, full of technical hurdles and setbacks. "For many decades, researchers have been able to get reactions to occur by using a lot of external heating to get the plasma hot," says Alex Zylstra of LLNL, a member of the NIF team. "In a burning plasma, which we have now created for the first time, the fusion reactions themselves provide most of the heating." Those conditions last only for about 100 trillionths of a second before the plasma's energy is dissipated.

"There was no one secret that allowed them to make this breakthrough but a whole bunch of smaller advances," Tynan says. To have any hope of getting the fusion process to sustain itself, the energy it produces should be deposited mostly in adjacent fuel layers rather than leaking from the capsule to heat the surroundings. This means that the capsule has to be sufficiently large and dense to keep the energy inside while still collapsing symmetrically—which is one of the issues the NIF team has cracked. The researchers have also tweaked the hohlraum's design to ensure its interior uniformly fills with x-rays, ultimately creating a smoother, stronger and more efficient implosion of the fuel capsule. "We had to learn how to better control the symmetry while making the implosion bigger," Hurricane says. Such improvements have required decades of effort. "It's been a very long trial-and-error process, guided by computations," Tynan says.

Of the experimental runs that the NIF researchers have reported, four conducted in 2020 and early 2021 exceeded the threshold fusion output for a burning plasma. The most recent of these were in February 2021, so "it clearly took some time for them to convince colleagues of the validity of their results," says Vladimir Tikhonchuk, a plasma physicist at the University of Bordeaux in France, who was not involved with the work. But they have evidently done so. "I truly believe publication of these papers is an important scientific event," Tikhonchuk adds.

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Making fusion viable requires more than merely burning plasma, however. For one thing, although the plasma is self-heating, it might still radiate more heat than it generates, including the energy lost when the implosion blows itself apart after reaching peak compression. "Even if you have burning, the reaction fizzles out if the radiative losses are too high," Tynan says. But the NIF team notes that, in one of its runs, the heating exceeded such losses.

That brings the scientists closer to the next big goal: ignition, where the net energy release from the fusion reaction exceeds the energy injected to produce it. On average, they can produce about 0.17 megajoule of fusion energy for an input laser energy of 1.9 megajoules. In other words, these NIF shots channel the energetic equivalent of a half-kilogram of exploding TNT into the tiny hohlraum only to get about 10 times less energy out. But that is still close enough to the break-even point to get fusion researchers fired up. "They are right on the threshold of achieving a propagating ignition burn," Tynan says.

Lancaster is optimistic about that. "We are now in a regime where modest improvements can create massive gains in output energy," she says. "We have definitely moved from an 'if' to a 'when' for ignition."

Even achieving ignition would be just the end of the beginning for fusion. For one thing, net energy gain must not only be demonstrated but also improved to compensate for inefficiencies in converting the heat into electricity. Better methods must also be developed for on-site production and handling of tritium to use as fuel. And in the specific case of inertial-confinement fusion, the exquisitely designed fuel capsules must somehow be made in abundance—and on the cheap. "Right now they cost $1 million and are custom pieces of kit made in the lab," Tynan says. But for any inertial fusion power plant to turn a profit, "you have to be able to make hundreds of thousands of them a day at 10 cents a piece." And these spectacular results for burning plasma in inertial confinement "do not really translate to tokamaks" at all, Hurricane warns.

"People working in this domain understand very well that there is a large gap between the [eventual] demonstration of ignition and a commercial fusion reactor," Tikhonchuk says. That gap certainly will not be closed at NIF, which is geared toward exploring the basic physics of fusion, especially in the context of nuclear stockpile management and national security. "We do not yet have lasers of a needed energy and power operating with a repetition rate of a few shots per second," Tikhonchuk adds—although Lancaster says that these "are well on the way, with big programs in the U.K., the U.S., France and Germany, for example."

"Now that NIF has demonstrated that [burning plasma conditions] can be done in a controlled laboratory setting," Norreys says, solutions to the remaining challenges "need to be studied in the coming years with renewed vigor."
"The challenge is [pivoting] from 'Is the physics even possible?' to 'Can we engineer a viable system that has sufficient lifetime and that is safe enough and do all those things at an affordable price?'" Tynan says. "That's still the big open question in front of the research community."

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Demand For Electric Cables Expands

By Perry Sioshansi | January 2022 | EEnergy Informer

In this edition of EEnergy Informer Perry Sioshansi states that it should come as no surprise that as more of the new capacity investments in power generation are shifted to renewables, the demand for cables to deliver the electricity from solar and wind plants to load centers increases. But what is new is that distances considered for transmitting have increased as it is now

considered economic to transmit power not only across state lines or to neighboring countries but across continents. As previously reported in this newsletter, renewable investors and developers are now looking into schemes where solar and wind energy can be exported from sunny Morocco or Australia to the UK or Singapore, respectively.

Renewable UK, for example, says the market for offshore wind farm cables will grow exponentially. According to its Offshore Wind Project Intelligence Report – Cables Edition, released in mid Nov 2021, more than 63,200 km (40,000 miles) of cables are expected to be installed by the end of 2030 globally compared to under 9,700 km (6,000 miles) which were installed by the end of 2020.

Additionally, nearly 40,000 km (25,000 miles) of export cables are forecast to be laid globally by the end of the decade – compared with 7,500 km (4,700 miles) at the end of last year. Currently the biggest offshore wind markets are in China, the UK, the USA, Sweden, and Vietnam – but as more wind farms move offshore, other countries are expected to join.

A similar trend is expected in utility-scale solar farms, which aim to transmit power over ever longer distances as more are developed over the coming decades. Once the local markets are saturated, it makes sense to transmit power to markets farther away. Sunny areas where the land is plentiful and cheap will be transmitting power to areas where the demand and prices are the highest.

Power can be transmitted across long distances with minimal losses using high voltage DC lines. Which explain why the market for long-distance electrical cables is literally exploding, which is likely to lead to supply-chain bottlenecks .

Heading Off Southern California Wildfires: Distribution Open Phase Detection

By Brendan Kirkpatrick , Reshma Ramdoss , Vahe Bolbolian , Arianna Ojeda , Andrew Swisher , Jesse Rorabaugh | 21 January 2022 | T & D World

Applying computer models and phase detection, SCE seeks to protect fire-prone areas by cutting power to falling lines before they touch the ground,

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Overcurrent protection is a common practice for the detection of faults on the distribution system, including downed wire. It is an appropriate and industry accepted methodology for system protection; however, in certain downed conductor scenarios, risks associated from shock and ignitions may still exist due to the variation in fault impedance.

If the fault impedance is high enough, the fault may not be detectable by typical overcurrent relays, due to very small current flow to ground. Even when over-current protection operates properly, arcing to vegetation may result in an ignition particularly during dry and windy conditions which can elevate fire risks.

As part of SCE's wildfire mitigation efforts, SCE began exploring methods to detect open phase conditions to de-energize overhead distribution electric systems before a conductor hits the ground to help further reduce risks associated with electrical shocks and fire ignition. There is a short time duration of around a second from the time a conductor separates to the moment it reaches earth.

Current measurement based open phase detection schemes are being applied on SCE's transmission system; however, voltage-based schemes are needed for distribution systems due to the complexity of load connections.
SCE developed a plan using existing devices equipped with three-phase voltage measurement capability to detect open phase conditions, which may be able to operate protective devices before conductors touch the ground. Additionally, model simulations proved critical in improving the logic to differentiate open phase conditions from fault events, increasing security of the system to avoid potential reliability impacts.

SCE recently completed installation of various rapid earth fault current limiter (REFCL) systems which also have the capability to detect some open circuit conditions in addition to the wildfire mitigation benefit they offer by limiting ground fault energy. At the same time, SCE continues to review how this detection scheme may function with other grid hardening technologies such as covered conductor.

Broken conductor at capacitor bank.

Detecting Open Phases

Although several novel approaches to detect open phase conditions using phasor measurement units (PMU) have been proposed, SCE sought a solution that could be applied with existing field devices and began by studying the symmetrical voltage components, positive sequence (V1), negative sequence (V2), and zero sequence (V0), produced by open-phase and faulted conditions.In recent years, SCE deployed automatic reclosers with integral voltage sensors on all three phases. These sensors provide phase voltage measurements, which in turn provides calculations for symmetrical components. SCE's team envisioned using end-point voltage measurements as a potentially viable solution to allow for open phase detection with minimal data transfer that has the potential to integrate with SCE's existing low-bandwidth radio system.

In this approach, end-of-line tie point recloser controller configured to detect an open phase condition sends a small packet message or trip command to the upstream device. The logic can also be applied back to the substation device though on SCE's system hardware updates are needed for expansion to these zones. The source device needs to be able to check that system condition is normal to prevent mis-operating for an open phase upstream and avoid a voltage disturbance cascading effect. It takes about one

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second for an open conductor to reach the ground level from a height of 30 feet.

To achieve the voltage measurements required for symmetrical voltage calculations, which are required for the open phase detection (OPD) scheme, the method uses either potential transformers (PT) or electronic voltage sensors connected in a wye (star) configuration. Delta connections are unable to provide zero sequence voltage, so they cannot be used.

An initial study focused on detecting an open circuit for a purely three-wire system as a large portion of SCE's overhead distribution circuitry is three-wire with no neutral extending from the substation. After the study, SCE formed a plan taking the calculated results into consideration and piloted it on a few distribution circuits. This method saw a series of misoperations where ground faults were detected as open phases.

At this point, it remained unclear how to validate the logic and define boundary conditions for the voltage settings to discriminate open phase events from traditional fault conditions. SCE's distribution system is a complex network of power lines with multiple transformer and load types. The distribution circuit will respond differently to loading conditions and system disturbances. A disturbance on a circuit would be affected by the system conditions prevailing at that moment.

SCE applied computer simulations to better understand the symmetrical voltages imposed on a distribution circuit for different system disturbances, including one-phase open versus two-phases open conditions. This makes system variations observable under both normal and abnormal operating conditions through an actual electric system modelled and simulated onto a computer platform.

To understand the behavior of a distribution main-line circuit in abnormal state, a detailed analysis was performed on a 12kV distribution system model. The model ran over 5,000 fault and open phase(s) simulations at multiple points throughout the circuit for collecting the voltage response at the tie device.

The data analysis indicated that for a conductor that breaks between the substation and the monitoring device downstream, its voltage collapses whereas the voltage on the non-broken conductors stays at nominal level. The results of the simulations also show that the way the load transformers are connected affect the system voltages. For a four-wire load that includes a neutral, the voltage of the broken wire falls close to zero. But when the load has three-wire only, with no neutral, the drop in voltage on the broken conductor is about half of the nominal phase to neutral voltage due to the backfeed through the transformer windings into the open phase.

When two conductors break, their respective voltages measured at the tie point are reduced compared to the unbroken phase, which still carries its system voltage. This is where the transformer wiring influences the results most clearly.

Voltage collapses to near zero on the two open phases when the load has a neutral connection. When the load is only connected phase to phase, the phase that is still close and energized will cause voltage to backfeed and induced to the two open phases causing an equivalent voltage on all the three phases.

A one open phase and a two open phase are discernable by the measured symmetrical voltages. While an open wire dictates the outcome of the zero sequence (V0) and negative sequence (V2) voltages, in the case of two open conductors, it is the zero sequence (V0) and positive sequence voltages (V1) that are the predominant factors.

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Open Phase Detection Logic

An OPD scheme allows for unique detection logic for each condition which clearly impacts a different number of conductors. This became critical for avoiding detecting of open phase conduction during a traditional fault event which often also creates a voltage collapse. The threshold values of the voltages were configured to help minimize detection of an open phase condition during a traditional fault event.

Distribution overhead pole with automatic recloser and control device.

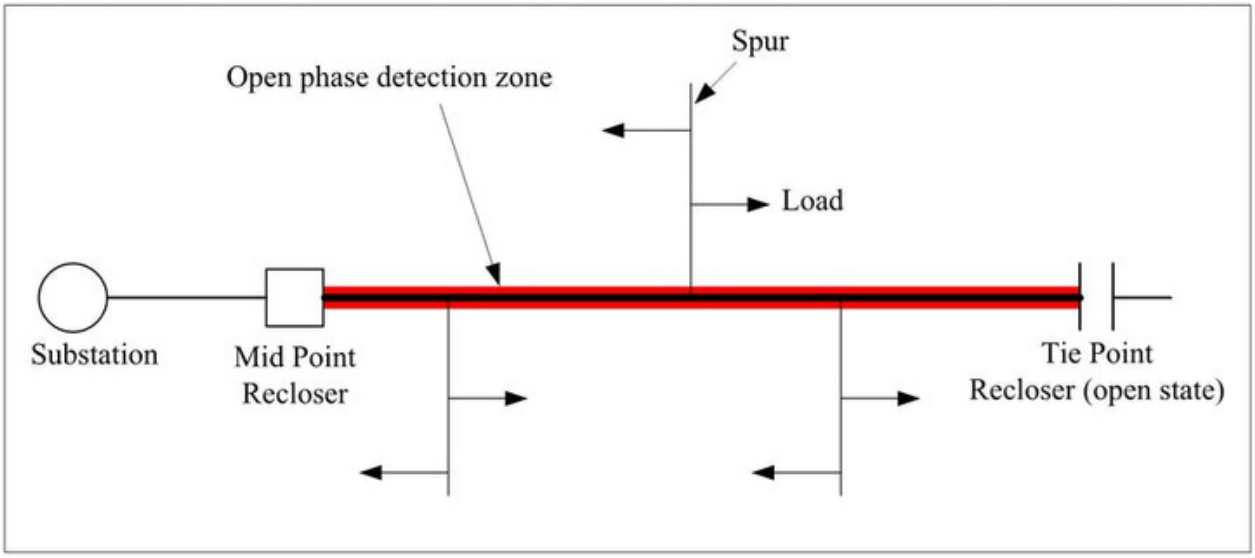
All the faults and open phase simulations values were applied to two equations developed entirely in house for a one open phase and two open phases conditions. Only the open phase conditions resulted in a true output as desired.

To date, more than thirty tie points recloser controllers on 12kV circuits have been programmed with the two-detection logic. A short timer was also added to delay the pickup on an open phase detection by a few cycles to filter out transients. Once an open condition is detected with the short timer, an alert is transmitted to the source recloser device via radio command. Since this scheme is in pilot stage, it is configured in an alarming mode with tripping disabled.

Real System Open Phase Occurrence

At least a dozen open phase alarms were generated since implementation of the logic in May 2020. One of them was issuing a constant warning over several hours. An analysis of the event report oscillography collected from the relay matched the simulated open phases. In short, it displayed all criteria satisfying an open conductor condition which justified the alarm signal. While troubleshooting between the tie and mid-point reclosers, the crew found a detached main line jumper with half a lug at its terminal and the barrel part still connected to a disconnect switch. The broken terminal connector caused the open phase. Since then, this termination is being retrofitted with higher duty rating to compensate for the strong Santa Ana winds.

INTERNATIONAL NEWS



Distribution system topology.

Many other detections are the results of single phase switching. These demonstrate the logic is correct as they are actual open phase conditions but also are a sign of the added complexity required to implement an OPD algorithm. It will be necessary to disable the OPD algorithm whenever single-phase switching is performed and re-enabled at the conclusion of the switching.

The open phase alarms have proven the significance of the computer simulations performed to refine the OPD logic and reject conditions related to faults. With OPD evaluation installations, SCE has demonstrated the capability to detect certain open phase conditions and avoid operation while connections remain intact. SCE continues to monitor installation performance and expects to expand the detection logic for larger scale evaluation.

Acknowledgements

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INTERNATIONAL NEWS

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Why Is It So Devilishly Hard To Kill off Coal?

By Perry Sioshansi | February 2022 | EEnergy Informer

Perry Sioshansi in the Feb edition of EEnergy Informer writes that in late Dec 2021, the International Energy Agency (IEA) released its Coal 2021 report which stated that, after falling in 2019 and 2020, global power generation from coal jumped 9% in 2021 to an all-time high of 10,350 TWhs. The rebound was blamed on the rapid economic recovery, which pushed up electricity

demand much faster than low-carbon supplies could keep up with. Moreover, the steep rise in natural gas prices increased demand for coal in a number of key markets in the US and Europe.

Commenting on the report's findings, IEA's Executive Director Fatih Birol said, "Coal is the single largest source of global carbon emissions, and this year's historically high level of coal power generation is a worrying sign of how far off track the world is in its efforts to put emissions into decline towards netzero".

But why is it so devilishly hard to kill off coal?

INTERNATIONAL NEWS

One gets a dose of reality reading the article titled Glencore's message to the planet, which appeared in the 1 Jan 2022 issue of The Economist. It chronicles how to phase out or phase down – has proven more difficult in practice. And while a few coal mining giants such as Rio Tinto abandoned coal starting in 2018, others including Glencore decided to acquire the discarded assets at discounted prices and have profited handsomely from the strategy.

The Economist points to another unexpected outcome. Anglo-American, which spun off its South African coal mining operations into a new company Thungela Resources, to cleanse itself of the dirty stuff, was surprised to find the new subsidiary's valuation quadrupled. Clearly not all investors care as much about the climate as the environmental activist Greta Thurnberg does.

Glencore's new CEO, Gary Nagle, according to The Economist, is unapologetic. "It views coal as a 'vital transition fuel' especially in Asia, where China and India account for 2/3 rd of global coal.

So this despite the pressure exerted by the environmentalists on the investment community, which in turn has pressured many fund managers to shun carbon-heavy companies from their portfolios. While the scheme seemed to go according to the script at first, abandoning coal has not accelerated its demise.

Another problem with putting pressure on multinationals to get out of coal is that they are most likely to spin off their polluting coal assets into subsidiaries – as Anglo-American did – in which case they fall into the hands of even greedier and more myopic investors whose only aim is to milk the assets and grind them to the ground before abandoning the mines and the miners once prices and/or the demand falls.

When this happens, no one will look after the miners or restore the mines. Large multinationals, one would hope, are more likely to clean up the mess before they leave or look after the workers.

So far, investors have not abandoned Glencore because rising demand and higher coal prices have been good for the bottom line. But things may change: "It is not clear investors would be so magnanimous were (coal) price to plunge," say due to flat or falling demand and lower prices.

The Economist concludes, "Only concerted government action to tax carbon emissions and redesign energy system will kill off king coal."

Capitalistic systems are about making money in the short to medium term, within the average tenure of a typical CEO. For politicians, the horizon of interest tends to be even shorter, 4-5 years in most democracies.

Which explains why it is devilishly hard to kill king coal.

CIRED INTERNATIONAL NEWS

CIRED2023:Destination Italy

After a successful online experience with CIRED 2021, it is now time to announce our next destination. The next major International Conference and Exhibition on Electricity Distribution will be held in Rome (Italy) on 12-15 June 2023.
Save the date in your agenda!

Participation in CIRED 2023 will offer a unique opportunity to meet with up to 2500 experts and benefits from face-to-face interaction with key decision leaders in the field of Electricity Distribution.

MORE INFORMATION ABOUT CIRED 2023

CIRED 2023 Exhibition
An exhibition gathering over 140 companies will be running throughout the conference.
Do not wait any longer to secure your place!

Important dates
April-May 2022: Call for papers available online
14 September 2022: Abstracts submission deadline
12-15 June 2023: CIRED 2023 Conference and Exhibition

CIRED PAPER

Improving personal safety in MV-networks through novel earth-fault current based feeder protection

Paper 695 | Madrid | June 2019

In this paper a novel method for earth-fault (EF) protection applicable in high-impedance earthed networks, especially in resonant earthed networks, is described. The innovative method is not based on traditional zero-sequence quantities (Uo, Io), but on accurate estimation of EF-current (IF) flowing at the fault location. Estimation of EF-current is done utilizing changes in phase currents measured at the beginning of the feeder due to an earth fault. Thanks to its novel operation principle, the method has several advantages over the traditional state-of-art EF-protection methods such as the wattmetric method. The method enables automatic adaptation of protection operation speed according to the estimated EF-current magnitude, including the harmonic content, which further enhances the accuracy and practicality of the novel protection method. The estimated EF-current magnitude can be converted into corresponding touch voltage magnitude, which enables direct compliance of protection operation to the electrical safety codes, such as EN50522.

In this paper, first the theory and operation principle of the new method is described. Then the performance of the suggested protection algorithm is validated using data from a field test in practical 20kV resonant earthed network. The results show that the novel method enables significant improvement on safety and overall dependability of the protection schemes used today.

DOWNLOAD PAPER

CIGRE INTERNATIONAL NEWS

CORONA TIMES

January 2022

A series of links to CIGRE Technical documents

CIGRE SCIENCE AND ENGINEERING - CSE023

Best papers of Centennial Paris Session featured in this edition:

- The evolution of the maintenance processes increases the operational availability and contribute to the operational efficiency of Itaipu Power Plant
- Verification of Withstand Capability for Very Fast Transients of a 200 MVA, 500 kV GSU-Transformer by Modelling and Testing
- CIGRE Reliability Survey on Equipment
- Dynamic Current Rating – Thermal Transient Response
- Hydrophobicity Classification of Composite Insulators Using Convolutional Neural Networks
- Digitalization solutions for substation planning, design, construction, operation and maintenance • A survey of the reliability of HVDC systems throughout the world during 2017-2018

IMPACT OF HIGH PENETRATION OF INVERTER BASED GENERATION ON SYSTEM INERTIA OF NETWORKS - TB851

The objective of JWG C2/C4.41 is to advise and formulate philosophies for system operations to prepare the on-going energy transition. Existing Primary Frequency Response studies were reviewed to analyse and mitigate against the impact of the reduction of synchronous inertial energy on power systems as a result of integration of non-synchronous renewable generation.

Various networks around the globe were used as case studies. A survey was carried out that looked at ways different system operators around the Globe dealt with the problem of reduction of system inertia and its impact on their networks. The integration of the existing knowledge between system operation and system performance, as well as the interaction with system planning, was seen as crucial to achieve the desired goals.

RECOMMENDATIONS FOR TESTING DC EXTRUDED CABLE SYSTEMS FOR POWER TRANSMISSION AT A RATED VOLTAGE UP TO AND INCLUDING 800 KV - TB852

The large number of projects and the quick development needed by the industry to match the demand of always more performing HVDC systems requires commonly shared and agreed testing method to speed up the time to market of technology solutions. This Technical Brochure is a pre-standardisation document which recommends a series of tests on extruded cables systems for DC power transmission (land or submarine cables with their accessories in fixed installations) up to and including 800 kV. The “extruded” insulation materials covered by this recommendation include thermoplastic polyolefins, mixtures of thermoplastic polyolefins, crosslinked polyolefins, mixtures thereof, and rubber-like materials.

UPCOMING EVENTS

Advancing Dynamic Customer Connections for Distributed Energy Resources (DER)

TUESDAY, 1 MARCH 2022 | QLD | VIEW EVENT

Overview:
Ergon Energy Network and Energex have been working closely with the industry to move from connecting passive Distributed Energy Resources (DER) with very limited 'smarts', to enabling a future where the dynamic connection of DER is the norm. The network business' were awarded Energy Networks Australia's 2021 Industry Innovation Read more.

Time: 3.30 PM - 5 PM AEST

Location: Online

Cost:
EESA members: $0
EA members: $30
Non-members: $30

Energy Speaker Series: Addressing challenges arising from renewable energy generation

1 MARCH | 3 MARCH 2022 | NSW ACT | VIEW EVENT

Overview:
Australia is undergoing a period of immense energy transformation, going from the third-most carbon-intensive country to one with a high penetration of renewable energy.
This three-part series showcases global examples of energy companies who have overcome various challenges in this transformation, including managing the impact of EVs, integrating renewable sources within existing networks... Read more.

Time: 3.30 PM - 5 PM AEST

Online webinar

Cost:
FREE

Snowy 2.0 underground project overview and update

TUESDAY, 8 MARCH 2022 | NSW ACT | VIEW EVENT

Overview:
This presentation will cover project details of the underground works, as well as an introduction into the adopted risk sharing mechanism for the project.
Including a general snapshot of the underground activities as well as specific information related to:

Read more...

Time: 6 PM - 7.30 PM AEDT

Harricks Auditorium, Engineers Australia Sydney Office, 44 Market Street, Sydney
OR
Online via webinar

Cost:
EA members: $0
Non-members: $30

UPCOMING EVENTS

Transforming the grid with pole-mounted batteries

WEDNESDAY, 9 MARCH 2022 | VIC | VIEW EVENT

Overview:
United Energy is trialling 42 pole-mounted batteries. What is that I hear you ask? In simple terms we are in the process of installing 42 individual batteries on power poles to store and complement renewable energy.
The primary benefit of Battery Energy Storage Systems (BESS) is to provide network support Read more.

Time: 5 PM - 6 PM AEDT

Location: Online via Zoom

Cost:
EESA members: $0
EA members: $20
Non-members: $30

Introduction to PQ of Electrical Supply

9 - 10 MARCH 2022 | NSW ACT | VIEW EVENT

Overview:
The rapidly increasing installation of electronic equipment such as digital controls, computers and sensitive process control equipment has increased the susceptibility of utility customers to supply disturbances. In addition, the application of power electronic equipment with its higher energy efficiency and more effective control features... Read more.

Time: 2-day event

Location: Online

Cost: $1770

The revised Australian lightning protection standard AS1768

WEDNESDAY, 9 MARCH 2022 | NSW ACT | VIEW EVENT

Overview:
This presentation will examine the impact of the newly revised Australian lightning protection standard AS1768. The basis for changes to the risk assessment process with case studies to illustrate how it may be applied to a range of structure types will be presented. New material will be provided regarding surge protection equipment,.. Read more.

Time: 6 PM - 7 PM AEDT

Location: online via Zoom

Cost:
EESA members: $0
EA members: $20
Non-members: $30

UPCOMING EVENTS

Crypto mining - a threat to or an opportunity for renewable energies?

TUESDAY, 15 MARCH 2022 | **WA** | **VIEW EVENT**

Overview:
Huge energy consumption required in blockchain authentication and the consequent environmental impacts have cast doubt on the sustainability of Bitcoin and Proof of Work based Blockchain. These concerns have motivated the development of 'Green Mining initiatives' to fuel the participants (miners) with electricity generated by renewable... Read more.

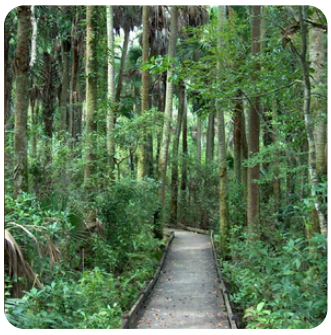
Time: 7.30 PM - 8.30 PM AWST (WA time)

Location: Engineers Australia WA Auditorium, 712 Murray Street, West Perth
OR
Online via Zoom

Cost:
EESA members: $0
EA members: $0
Non-members: $30

Achieving Net Zero for Energy in 2022

THURSDAY, 17 MARCH 2022 | **VIEW EVENT**



Overview:
oin our energy experts, Ed Hanna and Tony Giannikos as they take a look into the latest ways for your business to reach Net Zero in this free webinar.

They'll be live answering your questions and helping you understand your pathway towards Net Zero and providing you with an analysis of your options along the way.... Read more.

Time: 11 AM AEDT

Online via Zoom

Cost: free

Substation Design

6 - 7 APRIL 2022 | **NSW ACT** | **VIEW EVENT**

Overview:
Substations are a critical component of the electricity supply network whether it be to connect generators to transmission systems or deliver electricity to end users. This course provides an overview of the substation design process and includes description of the key components of substation design. The course is suitable for all... Read more.

Time: 2-day event

Location: Online

Cost: $1770

UPCOMING EVENTS

Synchronous services markets: maximising the capacity of existing transmission networks

WEDNESDAY, 11 MAY 2022 | **TAS** | **VIEW EVENT**

Overview:
Old synchronous generators are quickly being replaced by cleaner, cheaper providers but ones that can't provide synchronous services that used to come for free. If only there was a way to keep receiving these services, without the pollution.... Read more.

Time: 5:30 PM - 6:30 PM AEST

Location:
Hydro Tasmania, 4 Elizabeth Street, Hobart
OR
Online via Zoom

Cost:
EESA members: $0
EA members: $20
Non-members: $30

EESA

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