Remote work and climate change: Considerations for grid resilience in the 21st century

Received: 5th January, 2022

Jackie Ratner*
Senior Project Manager, National Center for Disaster Preparedness, USA

Vincent Westfallen**
Principal Engineer, Commonwealth Edison, USA

Susanna Aguilar†
Principal Analyst in Advanced Analytics, Commonwealth Edison, USA

Jeff Schlegelmilch††
Director, National Center for Disaster Preparedness, USA

Jackie Ratner

Vincent Westfallen

Jackie Ratner *is a Senior Project Manager at the National Center for Disaster Preparedness at Columbia University's Earth Institute, where she specialises in applied research approaches to disaster resilience. She holds a bachelor's degree in earth science from the University of North Carolina at Chapel Hill and was accepted into the doctoral programme at the University of Oxford.*

Vincent Westfallen *is a Principal Engineer in Distribution Capacity planning at Commonwealth Edison, where he has been involved in a broad range of activities, including field testing and distribution planning. He earned his Bachelor of Science in electrical engineering degree from the University of Illinois at Chicago.*

Susanna Aguilar *is Principal Analyst in Advanced Analytics at Commonwealth Edison, where she develops methodologies to evaluate the impact of advanced analytics applications on grid investment strategy and to value investments in grid reliability and resilience. Susanna holds a PhD in management science from Illinois Institute of Technology, where she previously worked as a postdoctoral researcher and adjunct faculty.*

Jeff Schlegelmilch *is a research scholar and the Director of the National Center for Disaster Preparedness at Columbia University's Earth Institute. His areas of expertise include public health preparedness, community resilience and the integration of private and public sector capabilities. He is the author of 'Rethinking Readiness: A Brief Guide to 21st- Century Megadisasters'. He holds a master's degree in public health from UMASS Amherst in health policy and management, and a master's degree in business administration from Quinnipiac University.*

*National Center for Disaster Preparedness,
7 Columbia Climate School,
Columbia University,
475 Riverside Dr,
Suite 401,
New York, NY 10115,
USA
E-mail: jjr2200@columbia.edu

**Commonwealth Edison,
2 Lincoln Center,
Oakbrook Terrace, IL 60181,
USA
E-mail: vincent.westfallen@ComEd.com

†Commonwealth Edison,
2 Lincoln Center,
Oakbrook Terrace, IL 60181,
USA
E-mail: susanne.aguilar@ComEd.com

††National Center for Disaster Preparedness,
Columbia Climate School,
Columbia University,
475 Riverside Dr, Suite 401,
New York, NY 10115,
USA
E-mail: js4645@columbia.edu

Journal of Business Continuity
& Emergency Planning
Vol. 16, No. 1, pp. 53–61
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1749–9216

ABSTRACT

This paper explores how the unprecedented dependence on remote work since the start of the COVID-19 pandemic has affected the demand for electricity. The paper discusses how the increased dependence on information and communication technologies has driven a shift in the daytime demand for power, from

Susanna Aguilar

Jeff Schlegelmilch

the commercial sector to the residential sector, prompting changes in the way electric utilities plan for peak load demand. As the article goes on to argue, this exposes the growing need for greater grid resilience in order to safeguard the supply of electricity in the face of increasingly frequent potential disruptions such as extreme weather events. The paper finds that emergency planners and responders, public agencies, utilities and other public and private sector stakeholders will need to collaborate ever more closely when devising and implementing solutions as well as when responding to emergencies.

Keywords: remote work, energy, electricity, grid, resilience

BACKGROUND

Resilience is a measure of societal ability to withstand or rapidly recover from adverse events. Access to electricity in the aftermath of a natural disaster is a key enabler of resilience.[1–3] As the frequency and intensity of climate-induced weather events is expected to increase, it is critical to take action to increase community resilience. This requires utilities, public and private sector stakeholders to develop frameworks that conceptualise how different institutions and premises within their service territories contribute to societal resilience in the aftermath of a disaster.[4,5] Such frameworks will underpin the prioritisation of grid investments based on their impact on societal resilience.[6] The COVID-19 pandemic has served to remind those engaged in developing these frameworks that societal dynamics can shift in response to significant events: the planning tools that are developed must be built to allow users to change key assumptions quickly and easily. The shift to remote work may also impact how reliability is valued.

Reliability, which assesses a utility's ability to provide adequate supply under credible contingencies, focuses on high-frequency, low-impact events. These events tend to be shorter in duration, with utilities using industry tools such as the interruption cost estimate (ICE) calculator to estimate the value of reliability.[7] These tools, however, are populated with data collected during an era with little overlap between residential and commercial space usage. Since then, however, there has been a significant increase in remote work, and thus a greater need for reliability in residential areas. This suggests that that updates to these tools may be required.

Understanding the complex dynamics that determine where demand occurs at a given time of day requires utilities and grid operators to collaborate with public and private sector stakeholders and academia. Grid improvements must be deployed in a manner that optimises flexibility to respond to shifts in demand.[8,9] Along with traditional system upgrades, demand response defined as 'changes in electric usage by demand-side resources in response to changes in the price of electricity or to incentive payments designed to reduce electricity usage when wholesale market prices are high or when system reliability is jeopardised'[10] will play an important role, but must be implemented to support energy justice. Similarly, decisions about investments in grid resilience must take into account social vulnerabilities and structural inequities in the communities they serve, and disaster relief programmes must be designed to overcome the barriers to electricity access that prevail among the most vulnerable populations.[11]

Enhancing the grid to promote societal resilience requires a rooted understanding in how the grid facilitates the provision of energy. Over the last century, the electric grid evolved as land was developed and feeders were designed to serve the mixed needs of residential and commercial loads.

Consumers are increasingly dependent on reliable power and expect more of it to come from clean sources. Power from renewable generators varies according to the weather and time of day. Distributed energy resources can contribute to local resilience, but also pose challenges as electricity flow becomes bidirectional. Meanwhile, electrification is both increasing load and changing load patterns on feeders. These complex dynamics (see Figure 1) must be considered as grid operators, utilities and public sector stakeholders aim to modernise the grid and develop strategies to increase grid resilience.[12–14]

Remote work arrangements add one more variable to an already complex mix. Safely and reliably keeping electricity flowing on the transmission and distribution systems requires careful planning to ensure that equipment limits are not exceeded. Most feeders in the grid do not regularly operate at full capacity as systems are designed with a level of redundancy to safeguard essential infrastructure and economic centres of activity even under peak load conditions. Grid flexibility plays an important role in ensuring supply to essential infrastructure and economic centres as demand rises and the frequency of adverse events increases.

A shift in electrical consumption such as the one caused by the increase in remote work arrangements has immediate implications for grid operators because a decrease in load from industrial and commercial customers coincides with an increase in load in residential locations. There are also long-term implications for grid planners: while the shift in load may not pose an immediate problem, reforecasts for peak load days may show that grid investments for increasing capacity or flexibility may be needed sooner or in different locations than previously anticipated.[15,16]

The rapid increase in remote work exacerbated a trend that had been observed in previous years. According to the Enerdata

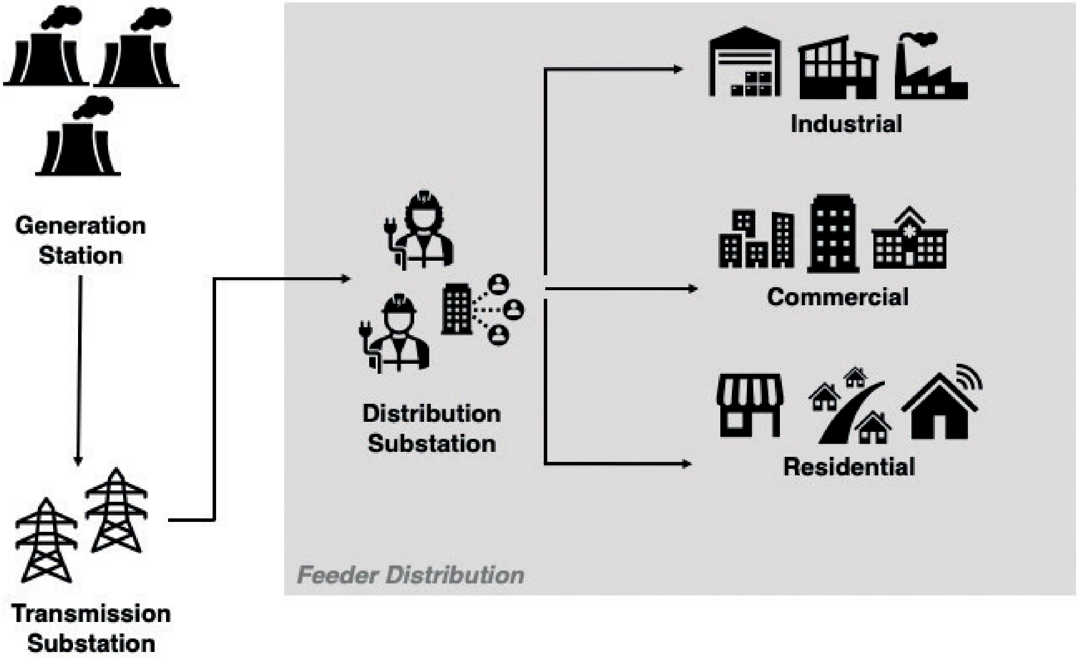

Figure 1 A schematic of feeder distribution in the power system

Global Energy Statistical Yearbook for 2019, US electrical consumption rose by 2.2 per cent in 2018:

> 'Most of this increase came from the residential sector (+6.2 per cent), mainly due to an increased electricity consumption for appliances (representing around half of the electricity consumption) and air-conditioning (nearly 90 per cent of US homes use centralised or house individual air conditioners)'.[17]

Historically, commercial and residential loads have followed a distinct pattern: commercial and industrial demand peak during the day, whereas residential demand peaks in the evening when commuters return home. The increase in remote work has caused increased daytime residential electricity usage for computing, lighting and space conditioning. Beyond the shutdowns during the early days of the pandemic, the increase in residential demand has not been significantly offset by decreases in the commercial sector because essential onsite operations were maintained.[18] There is some evidence that as companies have announced permanent shifts to remote work for at least some of their employees, people are leaving areas characterised by high cost of living. This trend may result in changes in daytime electricity consumption in the places where these remote employees settle, but these trends are not yet well understood.[19]

SHIFTING USAGE AND POTENTIAL IMPACTS

As a result of COVID-19, the residential component of the load on some feeders may be higher than usual during daytime hours and could result in higher than usual overall load if it overlaps with the commercial and industrial components of the load on that feeder. Figure 2 shows an example of the different times during the day when residential load and non-residential load typically peak.

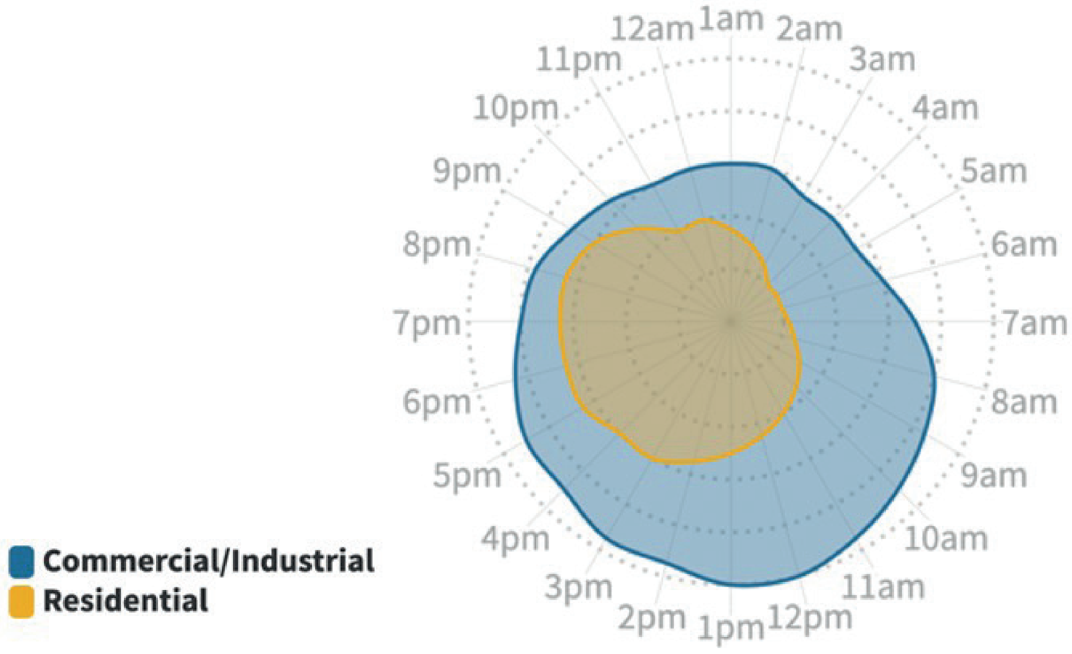

Figure 2 Peak electric demand by hour of day

If the residential peak that traditionally occurred in the early evening when many people are returning home from work shifts to coincide with commercial and industrial load peaks earlier in the day, the total load that must be served by a feeder could increase. Up to 56 per cent of the US workforce have jobs that could be completed 100 per cent remotely, but many companies only enabled full-time remote work when the COVID-19 pandemic became a global threat. With many states ordering non-essential personnel to remain at home to mitigate the spread of COVID-19, employers had to adapt operations quickly to support a distributed workforce. Making these adaptations in the first place may have removed one of the more significant obstacles to enabling more remote work: some estimates suggest that as much as 30 per cent of the workforce may permanently continue to work at least partially remotely even after the COVID-19 pandemic ceases to be a significant threat. Sources cite average savings of US$11,000 per year for each employee that works at home at least half the time, while most remote workers report an increase in job satisfaction and outlook.[20] Electric utilities are anticipating that the increase in remote work is at least in part a permanent shift, as many employers and employees alike have seen the benefits of remote work.

ADDITIONAL CHALLENGES

Investment in information and communications technologies (ICT) infrastructure has grown exponentially since the adolescence of the internet era. Today, ICT, which includes computers, smartphones, the Internet and data centres, demands about 2 per cent of global electricity, with roughly the same carbon footprint as the aviation industry.[21] By 2030, this could rise to account for anything from 8 to 20 per cent of global electricity demand. The largest consumers of ICT electricity are warehouses of computers and the infrastructure that supports the internet and data centres that carry and safeguard data and computational processes for individuals and corporations.

Whereas many large organisations have previously hosted their own data centres on-site, as many as 25 per cent of these privately held computer stacks are estimated to be ‘zombies’ — consuming energy while contributing nothing.[22] This points to a trend: commercial centres are increasingly outsourcing data storage and computer operations to data centres, which can be located anywhere in the country or world. Consequently, the ‘switchboard’ for economic activity is no longer centrally located on-site at economic hubs in commercial areas; neither is it generating traditional load patterns. Furthermore, economic activities are increasingly happening not just in commercial areas, but in residential ones — involving people working at home fulfilling purchasing orders, filing payroll, and innumerable other job functions. Not only does this affect where energy demand occurs, but it also suggests that residential power outages increasingly have an impact on business continuity, which has implications for the companies that employ workers affected by an outage and broader economic stability. In order to maximise the societal benefits of investments in grid resilience, these dynamics must be captured through resilience frameworks, metrics and planning tools.[23]

BUILDING GRID RESILIENCE

Electric utilities have been planning for a more flexible and resilient grid in recent years to respond to the challenges of the climate crisis and cyber security threats. Concurrently, electrical infrastructure is being redesigned to support the integration of renewable generation. This includes integrating distributed energy resources (DER) like solar photovoltaic (PV) and energy storage on the grid and introducing microgrid technology to increase resilience.[24–26]

In Chicago, the Bronzeville Community Microgrid (BCM), the first utility-operated microgrid cluster, is helping demonstrate how a microgrid controller can leverage all of these technologies to foster resilience in communities. Microgrids offer major resilience benefits when designed as part of a larger grid.[27–31] The main function of a microgrid is the ability to work in an islanded condition completely independent of the rest of the grid. In the event of a power outage, a microgrid can act independently, continuing to provide critical power to communities, essential institutions, and first responders during disasters. As they can operate while an outage affects the rest of the grid, microgrids can strengthen grid resilience and help mitigate grid disturbances while simultaneously functioning as a grid resource for faster system response and recovery.[32–34] Another benefit is the use of local sources of energy to serve local loads, helping reduce energy losses in transmission and distribution, further increasing the efficiency of the distribution system.

Microgrid islanding capability is particularly important given the increasing extreme weather events brought on by the climate crisis. The benefits of the BCM extend to surrounding communities that can access critical services within the microgrid footprint. This foundation of resilience in Bronzeville is not just the story of a microgrid cluster or a series of new technologies, however. Resilient infrastructure is only as strong as the community it serves, and a deeper function of the BCM is to help the neighbourhood of Bronzeville in its work to become more socially and economically resilient as well.[35,36]

A resilient grid is a crucial enabler of social and economic resilience. As seen with examples like the BCM, the role of the electric utility is starting to expand from energy provision to engaging with communities to reimagine how clean, resilient energy can support economic development and public health. Together, utility companies and the communities they serve are collaborating to achieve collective local objectives for improved quality of life and a clean environment. This new model demonstrates community resilience through the opportunities, technologies and programmes it launches. For example, in Bronzeville, a mobility service utilising electric vehicles and charging infrastructure was launched to solve a community-identified need to improve senior citizen mobility. While supporting that goal, the programme also creates jobs, builds connections, and increases the social and economic resilience of the neighbourhood.

As models for living and working shift to meet the increasing demands of a digital age, it is becoming clearer that a more modular grid design that enables DER is needed to reinforce existing infrastructure and create a more flexible power system and prepare for many changes to the grid in the next decade. This is why demonstration projects like the BCM are so significant — the learnings gained in terms of integrating DER will prepare for changes across the whole system to increase resilience.

CONCLUSION

While the economy, electric utilities and ICT have historically been strongly linked, the COVID-19 pandemic has illustrated that the global challenges of the future will require more intentional investments in infrastructures that enhance societal resilience. At this point, it is impossible to say how permanent the growth in remote work will be once the threat posed by COVID-19 becomes less acute. But now that many employers have a much larger remote capable workforce, grid planners must consider that a large proportion of that workforce will maintain some flexibility with regards to work location indefinitely. The grid, in turn, will need to become more flexible.[37,38] Just like the significant investment employers made in enabling remote work, investments in grid flexibility will contribute to resilience and society's ability to overcome the challenges of disruptive events in the future.

REFERENCES

(1) National Academies of Sciences, Engineering, and Medicine (2017) *Enhancing the Resilience of the Nation's Electricity System*, The National Academies Press, Washington, DC.

(2) Baik, S., Morgan, M. G. and Davis, A. L. (2018) 'Providing limited local electric service during a major grid outage: A first assessment based on customer willingness to pay', *Risk Analysis*, Vol. 38, No. 2, pp. 272–282.

(3) Birol, F. (2020) 'The coronavirus crisis reminds us that electricity is more indispensable than ever', available at: https://www.iea.org/commentaries/the-coronavirus-crisis-reminds-us-that-electricity-is-more-indispensable-than-ever (accessed 10th June, 2022).

(4) Shandiz, S., Foliente, G., Rismanchi, B., Wachtel, A. and Jeffers, R. (2020) 'Resilience framework and metrics for energy master planning of communities', *Energy*, Vol. 203, 117856.

(5) Jeffers, R., Hightower, M., Brodsky, N., Baca, M., Wachtel, A., Walsh, S., Aamir, M., Gibson, J., Fogleman, W., Peplinski, W., Vugrin, E., Ewers, M., Pasqualini, D. and Ambrosiano, J. (2017) 'A Grid Modernization Approach for Community Resilience: Application to New Orleans, LA', available at: https://www.osti.gov/biblio/1510648 (accessed 10th June, 2022).

(6) Chiu, B., Brown, S., Immerman, D., Khodaei, A., Liu, J., Mazurek, J., Novosel, D., Paaso, A., Rahmatian, F., Agüero, J., Vaiman, M. (2020) 'Resilience Framework, Methods, and Metrics for the Electricity Sector', IEEE PES Technical Report, available at: https://resourcecenter.ieee-pes.org/publications/technical-reports/PES_TP_TR83_ITSLC_102920.html (accessed 10th June, 2022).

(7) Sullivan, M., Collins, M., Schellenberg, J. and Larsen, P. (2018) 'Estimating power system interruption costs: A guidebook for electric utilities', available at: https://www.osti.gov/biblio/1462980-estimating-power-system-interruption-costs-guidebook-electric-utilities (accessed 10th June, 2022).

(8) Federal Energy Regulatory Commission (2011) 'Assessment of demand response and advanced metering', available at: http:// www.ferc.gov/legal/staff-reports/2010-dr-report.pdf (accessed 10th June, 2022).

(9) McCauley, D., Ramasar, V., Heffron, R. J., Sovacool, B. K., Mebratu, D. and Mundaca, L. (2019) 'Energy justice in the transition to low carbon energy systems: Exploring key themes in interdisciplinary research', *Applied Energy*, Vol. 233, pp. 916–921.

(10) Sullivan, ref. 7 above.

(11) Xu, X. and Chen, C. (2019) 'Energy efficiency and energy justice for US low-income households: An analysis of multifaceted challenges and potential', *Energy Policy*, Vol. 128, pp. 763–774.

(12) Domingue, S. J. and Emrich, C. T. (2019) 'Social vulnerability and procedural equity: Exploring the distribution of disaster aid across counties in the United States', *American Review of Public Administration*, Vol. 49, No. 8, pp. 897–913.

(13) Heffron, R., Körner, M., Schöpf, M., Wagner, J. and Weibelzahl, M.

(2021) 'The role of flexibility in the light of the COVID-19 pandemic and beyond: Contributing to a sustainable and resilient energy future in Europe', *Renewable and Sustainable Energy Reviews*, Vol. 140, 110743.

(14) Romero Aguero, J. and Khodaei, A. (2018) 'Grid modernization, DER integration & utility business models – trends & challenges', *IEEE Power and Energy Magazine*, Vol. 16, No. 2, pp. 112–121.

(15) Domingue, ref. 12 above

(16) Lund, P. D., Lindgren, J., Mikkola, J. and Salpakari, J. (2015) 'Review of energy system flexibility measures to enable high levels of variable renewable electricity', *Renewable and Sustainable Energy Reviews*, Vol. 45, pp. 785–807.

(17) Papaefthymiou, G., Haesen, E. and Sach, T. (2018) 'Power system flexibility tracker: Indicators to track flexibility progress towards high-RES systems', *Renewable Energy*, Vol. 127, pp. 1026–1035.

(18) Enerdata (2020) 'Enerdata Global Energy Statistical Yearbook 2019', available at: https://yearbook.enerdata.net/electricity/electricity-domestic-consumption-data.html (accessed 10th June, 2022).

(19) Cicala, S. (2020) 'Powering Work from Home', National Bureau of Economic Research Working Paper, available at: https://www.nber.org/papers/w27937 (accessed 10th June, 2022).

(20) Florida, R. and Ozimek, A. (March 2021) 'How remote work is reshaping America's urban geography', *Wall Street Journal*, available at: https://www.wsj.com/articles/how-remote-work-is-reshaping-americas-urban-geography-11614960100 (accessed 10th June, 2022).

(21) Global Workplace Analytics (n.d.) 'Work at home after COVID-19: our forecast', available at: https://globalworkplaceanalytics.com/work-at-home-after-covid-19-our-forecast (accessed 24th March, 2020).

(22) *Ibid*.

(23) Jones, N. (September 2018) 'How to stop data centres from gobbling up the world's electricity', *Nature*, available at: https://www.nature.com/articles/d41586-018-06610-y (accessed 24th March, 2020).

(24) Aguilar, S., Kean, E., Kushner, D., Larsen, P. and Schlegelmilch, J. (2021) 'Partnerships to enable smart cities and support resiliency', paper presented at the 2021 IEEE Conference on Technologies for Sustainability (SusTech), Irvine, CA, 22nd–24th April.

(25) Martinot, E. (2016) 'Grid integration of renewable energy: Flexibility, innovation, and experience', *Annual Review of Environment and Resources*, Vol. 41, No. 1, pp. 223–251.

(26) Papaefthymiou, G. and Dragoon, K. (2016) 'Towards 100% renewable energy systems: Uncapping power system flexibility', *Energy Policy*, Vol. 92, pp. 69–82.

(27) Deason, W. (2018) 'Comparison of 100% renewable energy system scenarios with a focus on flexibility and cost', *Renewable and Sustainable Energy Reviews*, Vol. 82, No. 3, pp. 3168–3178.

(28) Li, Z., Shahidehpour, M., Aminifar, F., Alabdulwahab, A. and Al-Turki, Y. (2017) 'Networked microgrids for enhancing the power system resilience', *Proceedings of the IEEE*, Vol. 105, No. 7, pp. 1289–1310.

(29) Kwasinski, A., Krishnamurthy, V., Song, J. and Sharma, R. (2012) 'Availability evaluation of microgrids for resistant power supply during natural disasters', *IEEE Transactions on Smart Grid*, Vol. 3, No. 4, pp. 2007–2018.

(30) Bahramirad, S., Katiraei, F., Khodaei, A., Kothandaraman, S. R., Lelic, M., Li, Z., Malekpour, A., Paaso, A. and Zamani, A. (2018) 'Research, Development, and Testing of a Master Controller with Applications to the Bronzeville Community Microgrid System', Department of Energy, Washington, DC.

(31) Zhou, Q., Shahidehpour, M., Paaso,

A., Bahramirad, S., Alabdulwahab, A. and Abusorrah, A. (2020) 'Distributed control and communication strategies in networked microgrids', *IEEE Communications Surveys & Tutorials*, Vol. 22, No. 4, pp. 2586–2633.
(32) Khodaei, A. (2014) 'Resiliency-oriented microgrid optimal scheduling', *IEEE Transactions on Smart Grid*, Vol. 5, No. 4, pp. 1584–1591.
(33) Che, L., Khodayar, M. and Shahidehpour, M. (2014) 'Only connect: Microgrids for distribution system restoration', *IEEE Power Energy Magazine*, Vol. 12, No. 1, pp. 70–81.
(34) Liu, X., Shahidehpour, M., Li, Z., Liu, X., Cao, Y. and Bie, Z. (2017) 'Microgrids for enhancing the power grid resilience in extreme conditions', *IEEE Transactions on Smart Grid*, Vol. 8, No. 2, pp. 589–597.
(35) Aguilar, ref. 24 above
(36) Schlegelmilch, J., Ratner, J., Kushner, D. and Aguilar, S. (2021) 'An Exercise in Resilience: Testing the Bronzeville Community Microgrid', Natural Hazards Center, Research Counts, available at: https://hazards.colorado.edu/news/research-counts/an-exercise-in-resilience-testing-the-bronzeville-community-microgrid (accessed 10th June, 2022).
(37) McCauley, ref. 9 above
(38) Venkata, S. S. M. and Hatziargyriou, N. (2015) 'Grid resilience: Elasticity is needed when facing catastrophes', *IEEE Power and Energy Magazine*, Vol. 13, No. 3, pp. 16–23.