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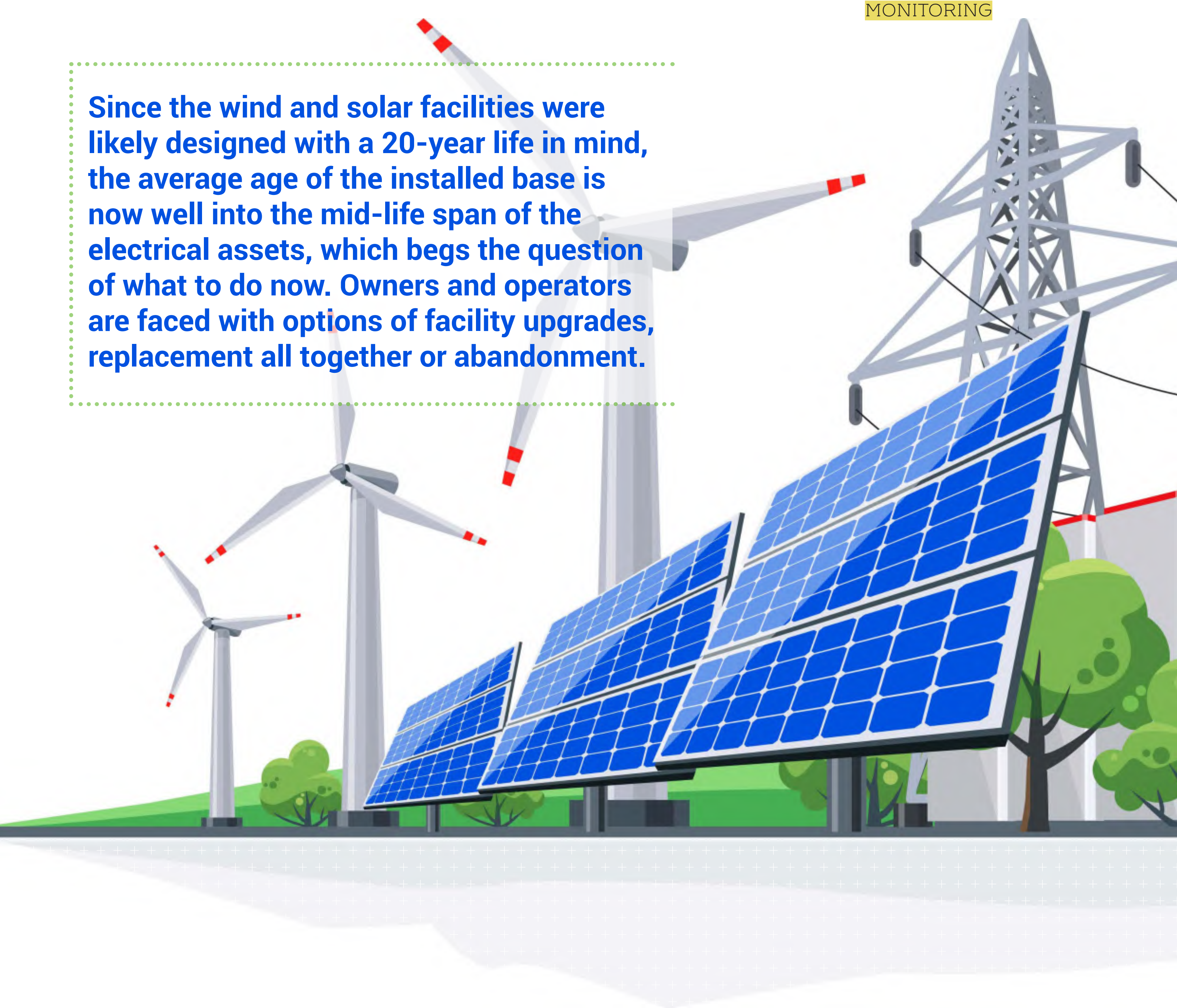

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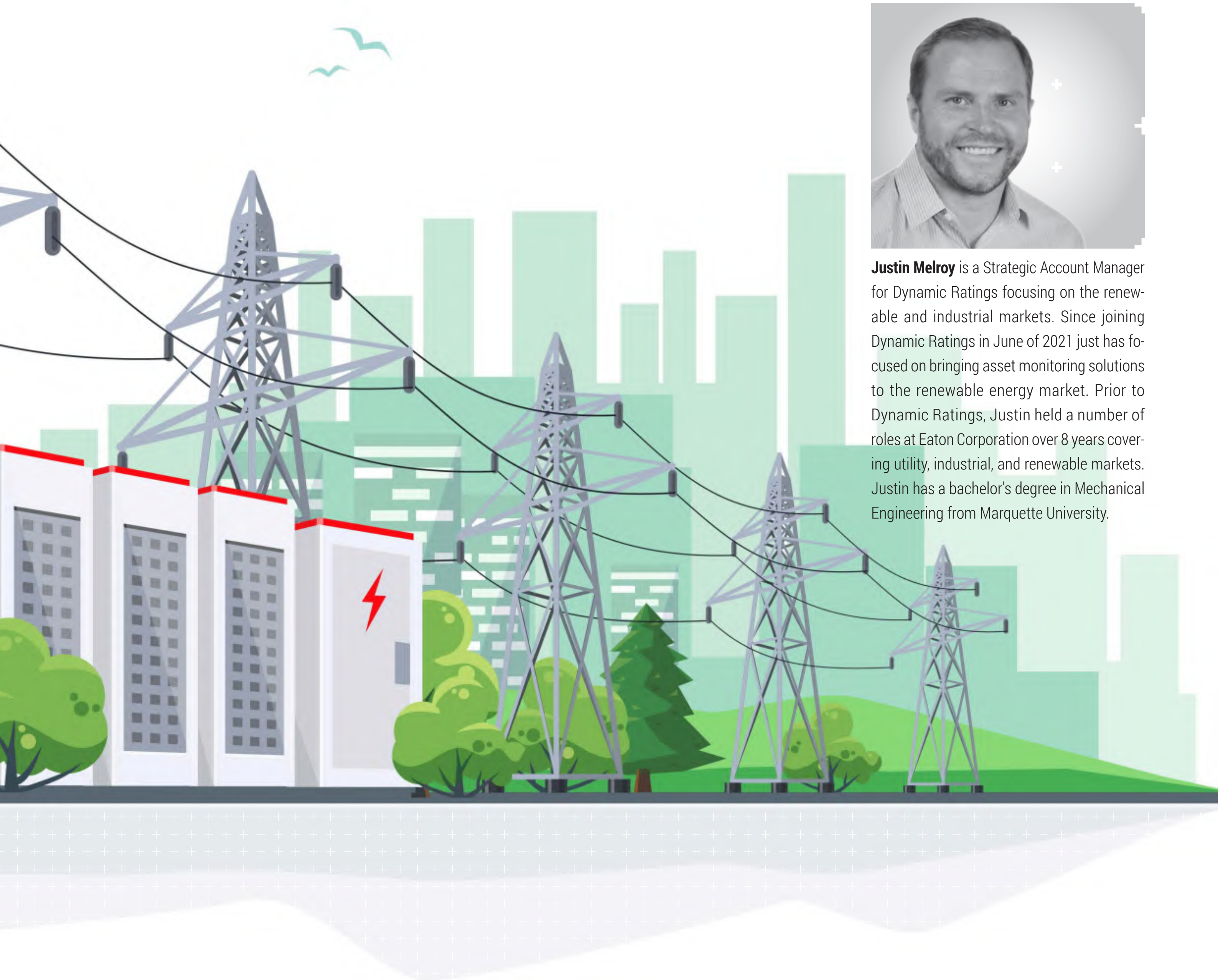
Deploying condition-based maintenance technologies to extend the life of renewable energy assets

by **Justin Melroy**

Wind and Solar energy operations have long been confined to a 15-20-year design life based on turbine and panel technologies, power purchase agreements (PPA) structures and tax incentives. In many cases the decisions to repower or dismantle renewable power operations comes down to the economics of long-term maintenance costs and equipment failure risks. By implementing condition-



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based maintenance technologies into renewable generation, energy providers can offset risk, extend the life of assets, and reduce the cost of repowering a facility. This article aims to shift the status quo of operations and maintenance providers, system designers, and energy users towards a culture of maximizing the lifespan of electrical assets to extend the life of a renewable operation.

The amount of renewable assets connected to the grid has exploded over the last decade, nearly quadrupling since 2011. This has made the renewable energy sector lucrative for investors as well as promising for climate advocates. The onset of renewable generation can be traced back to the 1970s when wind energy began taking off as a response to the oil shortages in the U.S. After a decade of research and development, California saw a great increase of wind turbines being installed. Then throughout the 1990s and 2000s, further developments were inspired by government tax and investment incentives.

Solar power was slower to adopt, as technology limited utility scale projects until the mid-2000s. In 2008 there was just 0.34 GW of U.S. solar. However, as the cost of solar has decreased and appetite for renewables has increased, the amount of solar in the U.S. today is estimated at 97.2 GW.

Since the wind and solar facility was likely designed with a 20-year life in mind, the average age of the installed base is now well into the mid-life span of the electrical assets. This begs to question of what to do now; owners and operators are faced with options of facility upgrades, replacement all together or abandonment.

Even with the rapid expansion in renewable energy over the past decade, "Renewables need to grow faster than our forecasts to close the gap with a pathway to net zero by 2050 [...]

For solar PV and wind, average annual additions would need to be almost double what we see in our main case forecast over the next five years," according to a recent IEA study [1]. Owners and operators may be able to close the gap by extending the life of current generation facilities and keeping capacity online beyond original design life. To do so, this would require best in class maintenance practices.

By implementing condition-based maintenance technologies into renewable generation, energy providers can offset risk, extend the life of assets, and reduce the cost of repowering a facility.

The Federal Energy Management Program (FEMP) suggests the following maintenance approaches for renewable energy facilities [2]:

"Modern, effective O&M programs rely on four basic approaches:

1. Reactive/corrective (includes run-to-failure) O&M: Fix/replace when broken
2. Preventive O&M: Time-based actions
3. Predictive O&M: Fix it before it breaks
4. Reliability-centered O&M: A strategic combination of the previous three approaches"

For well supported facilities, operations and maintenance (O&M) practices may have included routine oil samples and dissolved gas analysis, visual inspections and other offline testing of electrical equipment. However, for most of the installed base, the transformers are allowed to run to failure and substation equipment is monitored on cyclical basis only. As O&M budgets have been trimmed over time, the quality of the maintenance may have diminished.

Best practices for O&M indicate that investments in proactive maintenance are key to the O&M success. Continuous monitoring systems are an efficient means of collecting the necessary data to tackle proactive as well as predictive maintenance goals and keep the power plant running as efficiently as possible.

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Turbine blade and gearbox maintenance are some of the higher maintenance costs associated with a wind facility, leaving the electrical system to often get overlooked or lightly reviewed. However, online monitoring of substation transformers, turbine step up units, and switchgear protecting the substation transformer should be considered since the cost of the system will be absorbed by lower maintenance costs over time.

Online monitoring systems not only provide critical data for assessing the long-term health of the electrical equipment, but they also provide a significant reduction in down time and lower maintenance costs. Online monitoring allows operators to deploy condition-based maintenance and direct maintenance resources to known issues, rather than injecting potential problems by performing unnecessary work. Online monitoring also reduces unplanned outages and maintenance durations, keeping the power and revenue flowing in the right direction.

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In solar applications, the cost of vegetation maintenance and keeping the panels clean can account for as much as one third of the solar O&M costs. It is common that wind facilities require more maintenance and repair activities, whereas the maintenance requirements for solar tend to lean more towards site maintenance. This results in the generality that solar O&M costs are less than wind when viewed on a per kWh basis. However, electrical maintenance costs are relatively similar and provide equal benefit to extending the life of the equipment.

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Renewable applications are still the new kid on the block when it comes to the electrical world. In a system that is designed for stepping down power from transmission voltages to distribution levels, a whole host of data is available to determine the useful life calculations for utility transformers. Absent of rich data sets, it becomes important to begin gathering this data early in the life of the renewable asset. Asset owners increasingly rely on independent service providers, OEM provided, or self-performing maintenance work. However, with limited experience in field operations, the cost of maintenance contracts has increased significantly over the years. As a result, investors are increasingly looking for wind and solar farms that have implemented computerized maintenance management systems and asset management systems. Yet, there is still resistance to implement digital solutions as asset owners struggle to justify the up-front capital costs.

This resistance can be eased by considering the loss of production and increased maintenance costs associated with traditional maintenance methods. By allowing an electrical asset to run to failure, the risk of downtime is significantly higher than maintenance guided by an online monitoring system. When planned outages are taken

there is lower logistic costs since parts are not being expedited. Production losses can be mitigated by performing work when generation is at low points and overtime costs can be avoided.

In other industries, the business case for online monitoring can be made based on the impact of an unexpected loss of power impacting production and costing substantial equipment downtime. Similar value propositions can be made for renewable assets.

Failure to protect the substation transformer from partial discharge and bushing failures may result in catastrophic failures that could otherwise have been prevented or mitigated. Since 50% of bushing failures result in fires [3], the entire substation is put at risk. When compared to a total loss of a substation, monitoring costs for substation breakers and transformers are minor compared to the benefits of the system and the peace of mind in knowing the health of the equipment.

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Transformer loading conditions leading to premature failures in wind turbine installations are a significant concern for operators. Transformers are typically designed for constant load conditions, but due to the way that wind turbines are operated, the load conditions vary significantly, leading to cyclic loading and harsh operating conditions. These conditions often lead to premature failure making maintenance scheduling difficult. Continuous monitoring of these assets provides maintenance crews critical information on the health of the transformer, and can assist with the maintenance schedules, inventory planning, and operational consistency as transformers and switchgear are able to be removed from service prior to failure reducing the likelihood of damage to other equipment and cutting lost production time.
As transformer designs have been improved over time to account for some of the issues faced with early generation designs, new standards have been implemented to address the required changes [4]. However, it is still recommended to closely monitor transformer performance. Recommendations for transformers include temperature, pressure, liquid level and routine DGA sampling of the oil. When considering the remote location of these sites, it makes sense to transition to digital means of collecting the monitoring data and implementing online monitoring solutions.

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Further justification of continuous monitoring systems can be found by reviewing the data collected by transformer and switchgear monitoring systems. With capabilities to understand operating conditions over the life of the asset, owners can make better decisions on whether to replace the electrical equipment when turbine or panel equipment is due for upgrade. Therefore, reducing the cost to repower a facility or extend the life of an existing plant without adding unmanaged risk.

In conclusion, condition-based maintenance powered by continuous monitoring systems will play a substantial role in allowing renewable power operators to maximize the lifespan of the electrical assets on the system. Implementing such systems is a cost effective and proven solution to reduce O&M costs, extend asset life, improve planning cycles, and keep renewable facilities online longer. All these things will shift the culture of renewable operations and maintenance practices towards longevity and sustainability which is needed to address the gap in renewable generation demand and production capacity.

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