INNOVATION WITH PURPOSE
ALLEGRO microsystems

Efficiency and Renewables: How to Overcome the Challenges of Next-Generation Energy Systems

Contents

Clean Energy Needs to be Efficient, Safe and Affordable

Over the last few decades, there have been significant advancements in the development of clean energy systems and energy harvesting. However, overall adoption, lack of infrastructure and challenges with designing efficient, reliable and safe systems continue to pose difficulties within the industry.

According to the International Energy Agency (IEA), clean energy sources like hydro, wind, solar and tidal accounted for less than 6% of global electricity supply in 2022. Bioenergy and nuclear contributed 7% and 10% respectively. The remainder came from fossil-fuel pollutants.

Since clean energy sources remain a marginal part of the energy supply chain, it is critical that energy generated by these assets is captured, stored, converted and transmitted with the utmost minimal loss. Inefficient electrical technologies can waste up to 30% of the energy these systems produce and result in higher costs and environmental impacts. These challenges create a strong demand for innovative and reliable clean energy solutions that can meet customer needs and expectations – namely safety and affordability.

When designing clean energy systems like solar, wind, energy storage, heat pumps and electric vehicle (EV) chargers, engineers are expected to do more with less. Engineers must maximize energy utilization, enhance safety and reliability and deliver higher ROI – all while reducing their overall environmental footprint.

This e-book highlights many challenges faced by designers of clean energy systems and offers solutions to develop safe, reliable, high performance and affordable systems that can reach the market faster.

Chapter 1: Efficiency | Do More with Less

Projected to grow by an estimated 25% CAGR from 2019 to 2026, the solar energy market will continue to benefit from technological innovations that increase efficiency and reduce manufacturing costs. Today, investment in making existing systems more efficient is equal to that of new energy generation according to a recent IEA report. Engineers therefore need reliable and accurate sensor solutions that can work with a variety of voltage and current ranges, provide fast response times and integrate easily into their designs.

Figure 2. Continued pressure for smaller microinverters in solar panels demands an increase in the power levels that they are expected to handle. Source: anatioly_gleb/Adobe Stock

The Challenge

An abundance of oil, coal and other fossil fuels has powered modern society for well over a century. However, the drastic changes in the Earth's climate, as well as decreasing non-renewable energy resources supply, have prompted the transition to renewable energy sources. While combustion engines literally burn fuel to release energy – and more can simply be poured into a tank at a moment's notice – renewables typically require extra finesse to keep energy reservoirs efficiently "topped off."

The first step in solving this challenge is ensuring sufficient power generation from renewable sources. Additional solar panels, wind turbines and other clean sources will certainly equate to more energy, and peak efficiency means getting the most from these resources.

This requires a thoughtful engineering and technology solution, so panels and turbines make maximum use of the sometimes-limited sunlight and wind conditions. From there, power should be efficiently delivered to the grid or the point of use to avoid losses due to heat and potentially mismatched outputs.

Optimal power generation, transfer and delivery needs energy sensing solutions that are accurate and robust. With timely data in-hand, sensors can feed information to system controls, which can in turn automatically tune generation and transmission parameters.

Space and design efficiency must be a key consideration so that project requirements don't grow unchecked, potentially making an otherwise technically elegant or efficient solution unfeasible.

The Solution

To be effective, sensors used for energy extraction and conversion need to be accurate and robust over a wide range of operating environmental and electrical conditions. Current sensors – key to electrical energy extraction and conversion in clean energy applications – need to offer high levels of integration, operate reliably over various electrical and environmental conditions and offer the right performance levels to provide timely accuracy measurements to maximize energy transfer.

Since energy in simple terms is a result of electrical current delivered over a time period at a specific voltage level $E = (T * V \bullet C)$, increasing energy for the same period of time means increasing voltage or/and current. Increased current has the drawback of requiring larger transmission lines and potentially generating more heat, while increasing voltage does not have the same challenges - although proper insulation must be considered and implemented. Therefore, higher voltages can serve to increase transmission efficiency. If measurement sensors can work over a wide dynamic range of voltages and currents, they can deal with a wide range of situations, even including the measurement of multiple transmission instances in a single installation. From an engineering and design perspective, reuse of the same product within a design, or over multiple designs, means more familiarity for engineers and fewer spares that need to be kept on hand in the field. Magnetic-based current sensors offered by Allegro offers such that. They come in unique packages and implementations that are capable of handling currents up to 1000s A and voltages up to 1000s V.

In solar inverters, for instance, current sensors are integral for monitoring and controlling solar power systems. They measure the current produced by the solar panels, enabling the inverter to optimize power conversion from DC to AC, calculate panel efficiency and match the phase and magnitude of grid current. In conjunction with voltage measurements, high bandwidth and accurate current sensors aid the maximum power point tracking (MPPT) algorithms in the inverter to maximize energy harvest by adjusting the operating point based on sunlight intensity and temperature. For grid-tied systems, they offer feedback to match grid requirements, and in systems with storage, they monitor battery charge and discharge currents for optimal battery management.

As the market shifts to higher energy generation requirements, current sensors need to be able to offer high bandwidth, accurate measurements and low ohmic losses while operating at elevated electrical and environmental conditions. Allegro's recent current sensors offerings meet and exceed these requirements (ACS37002, ACS37003, ACS730).

On the other end of the clean energy spectrum, EV charging infrastructure can also be optimized to deliver energy with minimal losses. The use of quick current tracking sensors in high-speed switching circuits is especially important in these scenarios. The faster electrical equipment can get to the optimal state, the less energy is lost in the transition period.

On a component level, engineers should consider using sensor packages with low ohmic (i.e., electrically resistive) losses and excellent thermal dissipation to maximize current delivery. Ideally, sensor packages are fully integrated solutions that eliminate external components, potentially performing more than one job. If a package can, for instance, make measurements and supply its own power from available sources, it will eliminate additional expenses and engineering hassles. This can mean a smaller PCB with lower weight and greater overall efficiency when high-quality components are implemented.

Benefits of Efficient Design

Precise sensing solutions and the proper use of obtained data can mean maximized power conversion from one form (e.g., sunlight) to another (e.g., electrical power). This ultimately means greater utility for functions such as getting a vehicle from point A to B or powering a computer. Integrated precision components, such as those made by Allegro, can mean more power extraction in small circuit boards that still meet limited space requirements.

EFFICIENCY ACTION ITEMS:

- Pursue efficiency-centric design for significant customer and environmental benefits.
- Use sensors to optimize working parameters of renewable energy generation equipment and electrical infrastructure.
- Choose sensors that are precise and accurate over a wide range of temperatures and voltage ranges.
- Integrate sensors that are small, easy to incorporate and require very little power to operate.

Chapter 2: Reliability and Longevity | Extend Product Lifespan

Renewable energy systems are exposed to harsh environments and stress factors that can degrade their components and materials over time. Engineers need to find effective ways to extend the life of their designs, improve customer satisfaction and ultimately encourage repeat and long-term customers.

Figure 3. Implementing sensing solutions helps mitigate environmental threats to renewable energy systems.
Source: scharfsinn86/Adobe Stock

The Challenge

To varying degrees, any electromechanical system degrades over time. If renewable energy production devices need to be replaced or radically serviced before their anticipated lifetime is finished, their expense, and even their environmental impact, can soon become untenable.

Issues such as corrosion, vibration, thermal cycling and friction are experienced in the renewable energy space, and engineers must be especially cognizant of specific risks inherent to particular situations. Solar panels, for example, often become quite hot during the day, but quickly radiate heat at night. Offshore wind farms are constantly exposed to salty, corrosive air and extreme marine weather patterns.

Within these larger systems, specific components at risk include connectors, wires, switches, sensors, inverters, transformers, batteries, capacitors and resistors. Anything subject to movement, thermal cycling or other uncertain influences can be a target for wearing out over time

The Solution

Ruggedization is a key engineering parameter built into any renewable energy solution, but no system lasts forever. Certain systems fail before others due to variable manufacturing factors and how they are used in the field. Knowing the state of a system at any given time – and even being able to model inputs and outputs over a longer time span in the form of a virtual twin – can help engineers and technicians keep systems running at their optimal performance levels longer. This is where using advanced predictive maintenance methodologies makes a difference.

A full system picture here may mean tracking not just the renewable energy device itself and its orientation, but also local weather and other ambient conditions. Systems may track and consider where an asset resides on the Earth's surface, or above it in the case of wind turbines. Collected data can then be amalgamated with external information to gain a better picture of a system's behavior to perform maintenance and prepare for future conditions.

Applied sensors must operate over a wide temperature range to withstand conditions anywhere from rooftops and deserts, to tundra and extreme elevations. They must also offer excellent electromagnetic isolation so that variations in the local magnetic environment (a rotating electromagnetic turbine, for example) do not throw off readings. In practical terms, sensors should never be the maintenance subject or cause of machinery problems, but instead should be insulated against the fray of a system's main generating or storage purpose. One might say the sensor package is akin to a news reporter who tells the story, but never wants to be the story – the epic tale of long-term systems maintenance, as told by collected and interpreted data.

Benefits of a Long-Lasting Renewable Installation

The benefits of a rugged design with dependable and accurate sensing solutions extend to the end user, the equipment manufacturer and even the environment as a whole. The most immediate benefit is to the end user, who can potentially install a system and have it operating for years – even decades – without replacement or major overhaul. Predictive maintenance can be performed as needed based on accurate information. Along with the user avoiding hassle and expense, Earth's overall environment is saved as fewer solar panels, wind turbines and storage apparatuses will end up in a recycling process or in a landfill.

Equipment suppliers – when they are able to provide reliable renewable energy solutions and services – can count on enhanced reputations and customer loyalty. This can mean increased business and growth in the future, along with maintenance and monitoring contracts in the near term. Along with increased loyalty and reputation, as performance data is collected, manufacturers can continuously upgrade their designs. Good systems can be made even better in the next generation, continuously improving on the previous generation of products. Better designs mean less expense for the end-user in terms of replacement and repair, and optimizations can mean cost savings and performance benefits for both the manufacturer and users.

TIP

Allegro offers the largest portfolio of sensors on the market rated to 150°C (302°F) operating ambient temperature. Allegro sensors can measure conditions with striking accuracy over their rated temperature range. This combination of wide-ranging temperature usability, along with tight accuracy and precision, means Allegro products are a perfect partner for ensuring renewable equipment performs properly now, in the future and in the next design iteration. Allegro's expertise, knowledge and reputation gained over decades working on hardened sensing solutions in the automotive industry enables the company to develop customized and easy-to-integrate solutions for the clean energy market.

RELIABILITY ACTION ITEMS:

- Consider the overall nature of equipment and local environment in the design and installation phases.
- Implement predictive maintenance using known system and environmental conditions now and over time.
- Use rugged sensors specified for their particular environment.
- Leverage collected data to continuously drive towards design improvement.

Chapter 3: Safety | Mitigate Risks to Personnel and Equipment

Renewable energy systems involve high voltages, currents and temperatures that can pose serious hazards to the environment, operators, users and the grid. While fossil fuel-based systems have been improved over the last century, new clean energy applications are still in their relative infancy. If safety does not live up to or exceed fossil fuel alternatives, the reputation of renewables as a viable power option could be severely damaged.

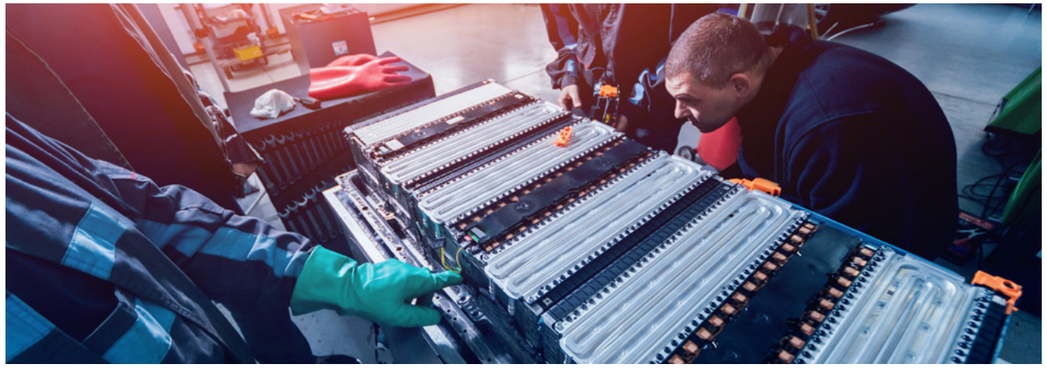

Figure 4. Proper sensing can help keep systems in virtually any industry performing at peak levels while maintaining strict user safety.
Source: romaset/Adobe Stock

The Challenge: High Voltage, High Current

Transferring electric charge to a vehicle, home backup system or other storage device is typically more complicated and nuanced than the pour-and-go liquid fossil fuel alternative. Charging a vehicle can take between a few minutes when using high-power DC systems (like Tesla's Superchargers) and hours when using a standard 120 V AC wall plug and adapter.

What sets one charge methodology apart from another is the amount of voltage and current in use, and whether DC or AC power is supplied by the plug. As voltage goes up, the danger of an uncontrolled and dangerous electrical arc increases, while the ability to supply a massive amount of current can make such shocks more hazardous, even deadly.

TIP: ELECTRIC VEHICLE SERVICE EQUIPMENT VS. BATTERY CHARGER

While we typically refer to what plugs into the wall and connects to an EV, along with static equipment as "chargers", this is a bit of a misnomer. Such connections are more properly referred to as electric vehicle service equipment, or EVSE. In a home installation, EVSE provides AC power, typically at 120 or 220 V, while more powerful devices are able to provide even higher voltages of power using DC current.

EVSE supplies power to the car, which has its own charging equipment onboard to "fuel up" its batteries. Because each car is different – even within a model – individual car batteries have different properties based on usage and manufacturing conditions. This onboard charging paradigm allows the individual vehicle to customize its charging profile to fit its individual battery pack. An array of on-car sensing and battery monitoring hardware is used to customize the charge profile.

Therefore, EVSE is primarily responsible for only the raw energy portion of maintaining a battery's health. Proper sensing, whether on an automobile or on EVSE, can help keep each side of the EV equipment equation performing at peak levels with strict user safety.

The Solution: Physical Isolation, Ultra-Fast Sensing

To mitigate risks in the EV and renewable energy space, systems must have safety integrated into their designs from the start. EV charging equipment, for example, uses a matched plug and receptacle setup designed for physical isolation, making misuse difficult. At the same time, physical barriers only go so far and can be defeated – either with enough persistence or because they simply break down with enough wear over time.

To combat the possibility – one might argue inevitability – of physical barriers being defeated, implementing sensing solutions can help monitor and prevent short circuits, overheating, fire, overvoltage and other anomalous conditions in renewable energy systems. Such sensing solutions must be extremely reliable, have dedicated fault pins that report back on their status, and have response times that are as fast as possible to minimize ill-effects.

Commercial solar inverters can operate into the 1,000 V range, while fast DC charging can take place at 850 V. Current sensors used in safety scenarios will ideally work over a wide range of temperatures and voltages with minimal performance drift, including voltages higher than typically expected. Broad voltage tolerance allows such sensors to report readings, even when levels are out of spec, and fault indication allows them to be used again (or quickly replaced) when faults are rectified. Ideally, such sensors will come in a small package size so that a full sensing suite doesn't inconveniently enlarge the design.

Benefits of Safety-Inherent Design and Sensing

Safety, as the motto goes, is everyone's business. Preventing injuries and deaths of workers and users alike is a requirement in all industries and sectors, not just renewable energy. Additionally, instances of injuries would ultimately mean more regulation, potentially slowing the proliferation of renewable energy assets – when there is precious little time to waste. Addressing safety concerns from the initial stages of project conception and planning will increase public acceptance and hasten the time from installation to generation.

On a more granular level, organizations with an impeccable safety record and a history of innovation in this space will have a competitive advantage. On the negative side, direct monetary costs from injuries can be high, and while in some sense incalculable, the moral cost of reckless design must be considered as well. Notably, not just personnel are at risk, but also local equipment and the overall grid itself, as a problem in one location can potentially propagate to affect other systems. Allegro's sensor offerings feature fast, robust solutions, with out-of-range detection and diagnostics capabilities, which are ideal for keeping both people and equipment safe.

SAFETY ACTION ITEMS:

- Integrate physical safety into system design.
- Design for normal electrical conditions and potential faulty states.
- Use sensor solutions to account for system wear, tampering and unsafe conditions (e.g., overheating).
- Use extremely reliable sensors with fault reporting to ensure human and equipment safety.

Chapter 4: Simplicity | Design with Ease, Accuracy and Confidence

As the world becomes increasingly electrified, the demand for energy and the requirements placed on the grid will continue to expand. Between automobile electrification, energy storage and renewable energy generation, a global need has developed for high-power-density technologies that can deliver more power output while using less space than legacy solutions. As one example, the market continues to push for smaller microinverters to be used in solar panels, while simultaneously expecting an increase in the power levels that they can handle.

Figure 5. Optimum power generation and delivery needs sensing solutions that are accurate, precise available in real-time and convenient. Source: zentilia/Adobe Stock

The Challenge: Efficient, High-Density Design

High density design addresses the challenges of cost, size and weight in electronic systems, but it presents a number of challenges. Notably, as physical sizes become smaller, proper isolation between high and low voltage systems – as well as humans – becomes more difficult. This is especially evident in systems that have limited space or mobility constraints, such as rooftop solar panels, electric vehicles and a wide range of portable devices.

Heat dissipation is also both essential and more challenging in smaller spaces. As more components are packed into a smaller space, each contributes its thermal load to the local environment. Overheating can reduce the life of components, and in extreme situations, potentially cause the breakdown of voltage isolation. This can lead to catastrophic failure and safety issues.

The Solution

Integrated devices with multiple functions streamline design processes by simplifying a circuit and its layout. Integrated solutions, such as high-voltage isolated gate drivers for GaN-based devices, reduce PCB space as well as BOM complexity and costs. Weight can also be reduced by eliminating components and board space required for their connections and operation. Allegro offers current sensors that provide reinforced isolation up to 1,600 Vrms without requiring external isolation components such as optocouplers or isolators. This allows for optimized PCB size and a simplified BOM, while ensuring safety and reliability.

Taking this a step further, turnkey solutions – ready-to-use components that do not require additional development or modification by the customer – may be implemented. These are packaged in small standard and custom footprints that fit the customer's application and requirements and simplify the design process by providing a complete and tested solution in one place that can be easily integrated into an overall system. Allegro offers turnkey solutions for motor, fan and LED drivers which provide all the necessary functions and features for operating these devices. Turnkey solutions mean engineers can spend less time sourcing components from multiple suppliers and more time innovating.

High-quality integrated solutions can also have benefits for mitigating heat generation. Allegro current sensors have an internal conductor resistance that is typically three to five times lower than using shunt resistors. This means not only better design efficiency, but also lesser heat dissipation. Proper sensing can also reduce size, weight and wiring costs, as a system can safely operate closer to its limits if real-time accurate statistics are known.

Benefits: Optimum Design Process

While reducing a PCB size by one component may seem like a nearly negligible difference, what about two components, ten, or more? One might also consider how these individually small improvements on a PCB reverberate through a design: smaller PCB, smaller enclosure, smaller housing & smaller overall system. Small changes eventually add up to a significant impact and make systems easier to install and integrate with existing infrastructure and equipment. Not to mention the savings in natural resources used in this equipment can lead to an overall better environment for all.

Of course, one design decision can have an outsized impact by itself, like Edison using a vacuum to keep a light bulb filament burning; or Bardeen, Shockley, and Brattain using semiconducting material to develop the transistor. Consider, however, that the Apple II (or even earlier computing devices like the Z1, Colossus or ENIAC) did not give rise to the modern iPhone or gaming laptop overnight. It was the steady pace of innovation that led to these massive improvements over a series of decades.

Of course, innovation does not happen in a vacuum in any technological realm, whether in computing or clean energy. Today's cutting-edge innovation may be what is needed to keep ahead, or even at pace, with competitors. Organizations that embody efficient design principles and are continuously innovating, while implementing new technologies into limited physical spaces, will have a significant competitive advantage going forward.

TIP

Allegro Power-Thru technology powers gate drivers using fully integrated system-in-package devices. This eliminates a range of extra components, along with the potential capacitive effects and interference of the associated PCB traces. More information about Power-Thru technology is found here, and this article outlines how it can be used to increase power density by reducing the number of power rails needed in a design.

SIMPLICITY ACTION ITEMS:

- Drive toward physically small designs–address inherent challenges such as heat dissipation and electrical isolation in confined spaces.
- Utilize integrated components, such as high-voltage GaN-based devices, to help reduce BOM complexity, costs and PCB space usage.
- Use turnkey solutions in industry-standard packages (such as Allegro Power-Thru components) to simplify designs.

Conclusion

Today, clean energy harvested from natural resources is just a fraction of the overall energy landscape. Despite ambitious benchmarks and goals from industry leaders, politicians, regulatory agencies, technologists and engineers, the world is lagging in renewable energy targets in many areas.

But hope is not lost, as innovative technologies and ideas continue to spring forth and incrementally drive this critical industry forward. Look no further than the sensing solutions put in place in the clean energy supply chain, as utilities and industries seek to harness every efficiency possible. These same sensors help electrical engineers grasp system reliability through real-time understanding and troubleshooting of issues and enables future designs to be ruggedized based on real data from the system in the field.

Safety is another important factor where advanced sensing solutions help. As the clean energy supply chain grows, and more consumers encounter these technologies, protecting individuals and property from high voltages, arcs and overheating is critical to their acceptance.

The final design philosophy for clean energy electrical systems is simplicity. These devices need to be small, easy to integrate and convenient to use. That makes the system safer, more user friendly and easier to redesign or retrofit down the road.

All in all, the renewable energy revolution might be powered by electricity, but making effective use of the resource requires advanced sensing solutions delivered by an industry leader.

Allegro MicroSystems, with a history of over 30 years of innovation, is working diligently to provide the innovative sensing solutions needed for the burgeoning clean energy field. The company has shipped more than 11 billion sensors over its 30-plus year history, with a reputation for rugged, reliable and innovative designs. This expertise applies perfectly to the renewable energy world – generation, storage and distribution – where sensor packages need to last for many years, while being easy to integrate into new designs.

Allegro is headquartered in Manchester, New Hampshire, with over 4,000 employees worldwide. It supports over 10,000 customers and works with leading global companies around the world to develop new renewable energy products and improve existing designs. Allegro has an extensive line of off-the-shelf products, and designs can be customized to meet specific applications.

To learn more about clean-energy solutions and how Allegro is helping move the world toward a more-sustainable future, visit allegromicro.com/cleanenergy.

INNOVATION WITH PURPOSE

ALLEGRO microsystems

AM064-12.23