Advantages of a Generator in Hybrid vs. Load Following Systems

Exploring efficiency and operational advantages in hybrid vs. load-following generator systems

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In this whitepaper, Convrg Innovations (Convrg) aims to discuss the distinctions and benefits inherent in two generator configurations: load-following and battery-charging (hybrid) systems.

A load-following generator is directly linked to the load, dynamically adjusting its output power based on real-time load demands. Conversely, a battery-charging generator involves a consistent load, comprising both regular consumption and battery charging components. This is managed through an inverter-charging system that optimizes the distribution of power between the load and battery charging, maintaining load stability. Upon reaching full battery charge, the generator is deactivated, with subsequent power supply sourced from the charged batteries.

PEAK SHAVING

Peak shaving, also known as load smoothing, refers to the strategic utilization of a battery system to bolster power supply during periods of heightened current demand, such as inrush events. This approach allows the system to exceed the capacity of the primary generator, effectively tapping into the battery reserves as a supplementary power reservoir. Ensuring the effective use of this process necessitates adept management, typically through a sophisticated battery management system.

Peak shaving serves a crucial purpose of averting generator overloading, presenting a notable advantage by mitigating the strain imposed on the generator and avoiding potential shutdown occurrences. Furthermore, this approach allows the system to accommodate high inrush loads, such as air compressors – an important component within our systems. This capability underscores the operational resilience of the overall setup, ensuring sustained performance even during periods of heightened demand.

REDUCED RUNTIME

A notable advantage gained using a hybrid system is the reduction in generator runtime. When the battery bank is fully charged, the generator can be disengaged, enabling the battery bank to assume the role of powering the system autonomously. This design finds practical application in our EPOD series, where the reduction in generator operating hours serves to significantly extend maintenance intervals and increase the reliability of our product. More information on our products reliable design can be found in the Improved Reliability: Discussing the Enhancements Made to our Products that Result in Increased Reliability article.

Better Generator Operation

MECHANICAL

Generators are engineered to operate around their specified rated power output and RPM, thereby yielding optimal efficiency. For continuous rated generators, peak efficiency is typically achieved within the load range of 70%-100% of their rated capacity. Sustaining a constant load within this optimal range results in a higher fuel-to-power ratio, leading to reduced fuel consumption for power generation. More formation on optimal loading and alternator sizing can be found in the Engine Modifications and Maximizing Maintenance Intervals article.

Sustained operation of the generator under heavier loads offers the distinct advantage of minimizing the frequency of start and stop cycles. This reduction in cycling contributes to diminished wear and tear on vital components such as the engine's alternator and battery, which often contend with substantial inrush currents during startup.

Exposing a generator to operation under colder temperatures, often due to insufficient load demands, may lead to wet stacking. This phenomenon stems from the exhausting of unburned fuel during operation, leading to the gradual buildup of residue within the combustion chamber. The consequences of wet stacking are twofold: it necessitates more frequent maintenance intervals, and contributes to a shortened overall operational lifespan of the generator system.

An additional issue encountered by generators during periods of low load is diminished operating pressures. The reduction in pressure within the cylinders contributes to inadequate sealing of piston rings, thereby inducing a cycle of degradation within the engine. Low seal pressure causes subpar combustion, leading to the accumulation of soot and unburned fuel that adversely affects piston rings and leads to the accumulation of carbon deposits. Carbon buildup, in turn, precipitates fouling of spark plugs, inducing a cascade of challenges ranging from compromised fuel efficiency to engine misfires.

Furthermore, compromised piston ring sealing results in the occurrence of glazing, a phenomenon characterized by the flash burning of piston lubricant. This effect disrupts the lubrication process, exacerbating the sealing problem. The interconnection of these issues forms a self-aggravating cycle, collectively undermining engine reliability and contributing to shortened maintenance intervals.

ELECTRICAL

The operational behavior of a generator in a load-following system inherently introduces variability, stemming from the inherent irregularities in power demand. This fluctuation presents a potential hazard to the reliable operation of the connected electrical devices.

Variations in load prompt the generator to experience "ramp-up" and "ramp-down" phases. During a ramp-up, which is initiated by a sudden load surge, the generator reacts by augmenting its output. To meet the heightened power requirements, the generator's frequency decreases, with a portion of the inertial energy being converted into electrical energy. This, in turn, is accompanied by a reduction in voltage levels. In situations where the frequency drop exceeds a certain threshold, it can potentially trigger an automatic generator shutdown for protective purposes.

Conversely, during a ramp-down, attributed to a decline in load, the generator's frequency exhibits a surge as it dissipates the excess energy that was previously being generated. This escalation in frequency is accompanied by a corresponding voltage spike.

The repercussions of frequency fluctuations extend to motor speed control across the entire system. Motors, such as those used in air compressors, are engineered to operate optimally within a designated frequency range. When frequency variations occur, these motors experience deratings, resulting in reduced efficiency and the potential for overheating.

Moreover, AC to DC conversion processes, such as battery chargers, rely on the integration of inductive and capacitive elements in their circuitry. These non-linear components require precise timing and frequencies for operation. Deviations from the specified frequency parameters lead to voltage ripples and unpredictable outputs, undermining the reliability and consistency of the conversion process.

In cases where a generator operates with a consistent load rather than adhering to load-following behavior, such as hybrid systems, a discernible improvement in voltage regulation becomes evident. This enhancement is directly linked to the sustained and heightened levels of RPM and load. When a generator operates in proximity to its full load capacity, it exhibits heightened resilience against voltage flicker—a phenomenon characterized by transient variations in voltage resulting from minor fluctuations in the load, which are inherent in operation. An analogy to comprehend this principle is likening RPM to the system's momentum, where greater momentum corresponds to heightened resistance against voltage variations induced by load changes.

The implementation of a hybrid system offers a solution to these challenges. This solution enables the generator to maintain peak efficiency levels, even during instances of reduced load demand. This capability is achieved by integrating battery charging to compensate for lower loads, thereby ensuring that the generator consistently operates within its optimal performance range. Additionally, our hybrid system serves as a safeguard against cold start incidents by also functioning as an Uninterruptible Power Supply (UPS). This ensures that during periods when the generator is inactive, whether due to generator malfunctions or during battery discharge cycles, the unit sustains an operational temperature. This is made possible through the incorporation of heaters and air compressors within the unit's design.

CHALLENGES

While the benefits of incorporating a hybrid system are substantial, it’s important to acknowledge and address the associated challenges. One of the most prominent is the occurrence of Total Harmonic Distortion (THD), which manifests when capacitive and inductive loads—often referred to as non-linear loads—are present within a system. Such loads result in a reduction of power factor and system efficiency. Non-linear loads are frequently encountered in power conversion scenarios, notably during battery charging processes, which can be done through battery chargers and inverters, both of which convert AC power to DC power.

In the context of a hybrid system, which relies heavily on battery charging, elevated THD levels can be induced in the power system. To mitigate these challenges, generator and battery charger sizing is an important consideration. Within the framework of the EPOD system, the mitigation strategy extends to diminishing THD by balancing phase power draw and using line reactors in strategic locations to counteract harmonics generated by problematic components.

SUMMARY

> **The hybrid system constitutes an important element within the solution offered by the EPOD. It serves as a tool for tackling generator-related challenges and augmenting overall operational eddiciency. The utilization of hybrid has garnered a substantial track record of success spanning numerous years.**

Particularly noteworthy is the well-established and widely-recognized application of hybrid systems within hybrid vehicles. These vehicular systems leverage similar principles and technologies to our solution, with a shared objective of optimizing power efficiency and curtailing emissions. Generators dedicated to battery charging have been shown to deliver superior efficiency in terms of labor and power utilization when compared to load-following generators. This is attributed to their capacity to optimize generator power generation and leverage the operational benefits offered by a power bank.

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