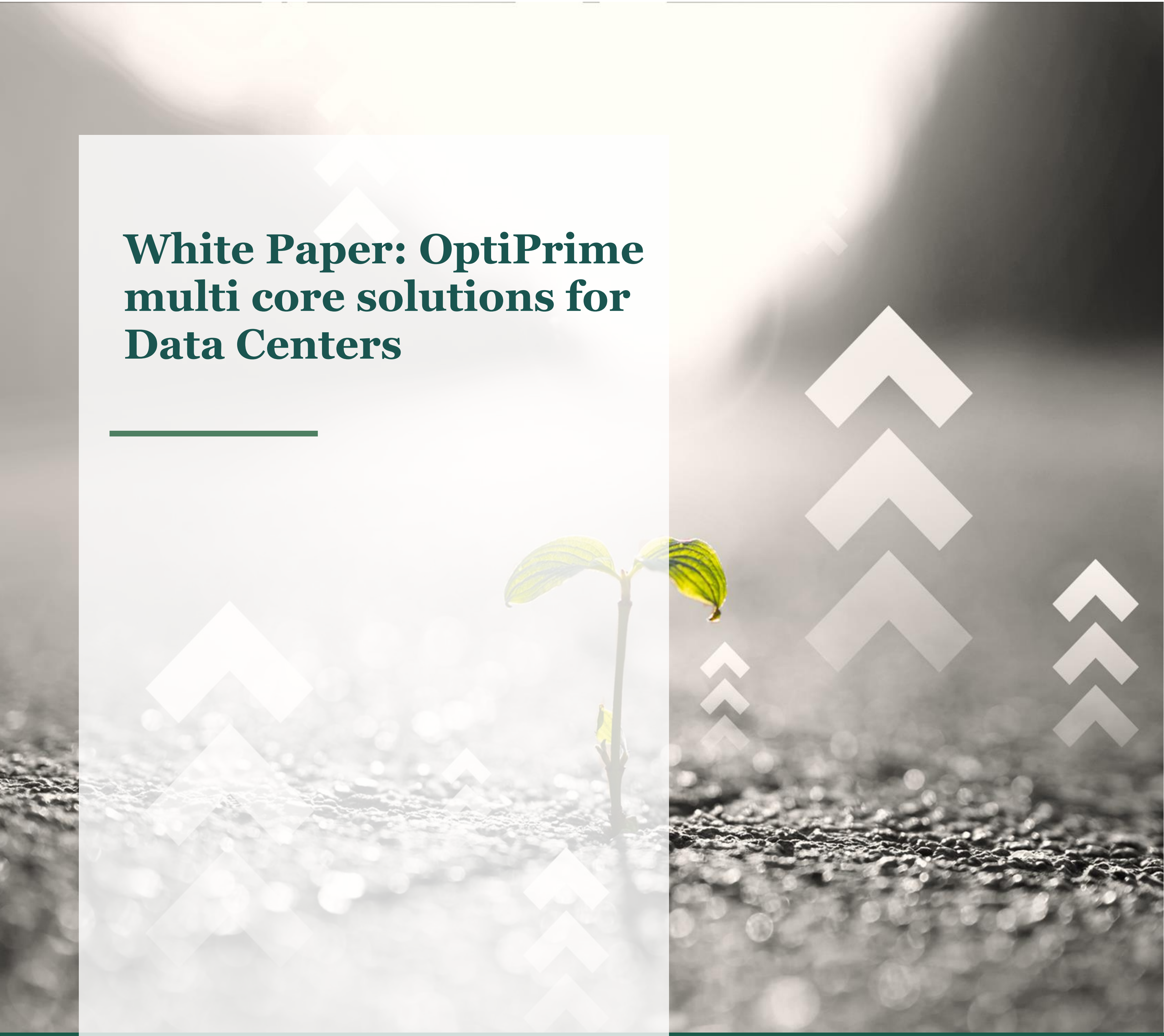


White Paper: OptiPrime multi core solutions for Data Centers

MARCH 20

Kirloskar Oil Engines Limited

Multi Core solutions for achieving net zero in Data Centers

Contents

Abstract

Data centers are the backbone of the digital economy, requiring uninterrupted power, optimal cooling, and high energy efficiency. The increasing computational load and the global shift towards sustainable energy solutions demand next generation gensets that can outperform traditional backup power solutions. Kirloskar Oil Engines Limited (KOEL) has introduced the OptiPrime Series, an advanced multicore power generation system, delivering superior fuel efficiency, redundancy, compact design, and seamless integration with data center infrastructure. This white paper explores how OptiPrime generators outperform competing solutions focusing on efficiency, cost-effectiveness, emissions compliance, integration flexibility, and reliability.

Introduction: The Power Challenge for Data Centers

In today's fast-paced world, the demand for reliable and uninterrupted power supply has never been greater. As industries, businesses, and essential services depend heavily on electricity, the role of diesel generators becomes crucial, especially in scenarios where power outages are not an option. Data centers are among the highest consumers of energy globally. They require continuous, redundant power systems to ensure zero downtime for mission-critical applications. While traditional diesel generators have been the standard for decades, they suffer from fuel inefficiencies, large footprints, poor load adaptability, and high emissions. A recent study at Kirloskar Oil Engines Limited studied >60,000 generator sets and 90% of the generator sets were found to be running at 50% load or lower!

OptiPrime range of Multi Core Power systems

To solve these issues, Kirloskar Oil Engines has introduced OptiPrime generators, which combine multiple cores of internal combustion engine (ICE) in a single, compact, and highly efficient genset. However, having multiple diesel generators is only part of the solution. Through OptiPrime we are providing factory-fitted pre-synchronized generators that truly ensure a stable and reliable power supply. Unlike traditional diesel gensets, OptiPrime offers significant advantages tailored for high-performance data centers:

Parameters	Standard DG	Kirloskar Powergen- OptiPrime
Scalability & Load Flexibility	❌ **Limited:** Cannot scale dynamically, must operate at full power even during low demand.	✅ **Better:** Engines can be turned on/off based on demand, improving part-load efficiency.
Operational Efficiency & Cost	❌ **Higher Initial Cost & Opex:** The cost of components increases exponentially as you go higher up in the cylinders (e.g. V18, V20, V24, V28, V30)	✅ **Lower CAPEX & Opex:** Factory fitted synchronization, and lower footprint ensures lowest cost of ownership and equivalent capex
Fuel Efficiency at Low Load	❌ **Less Efficient:** Large engines operate at reduced efficiency under part-load conditions.	✅ **More Efficient:** Load sharing optimizes fuel consumption by running only necessary engines.
Redundancy & Reliability	❌ **Single Point of Failure:** If one engine fails, entire power supply is at risk.	✅ **High Redundancy:** If one engine fails, the rest can continue running.
Footprint	❌ **Larger Footprint:** Larger footprint driven by size of single unit	✅ **Lowest product footprint:** Product is engineered to give you of the lowest product footprint in the industry
Specialised requirement- Advanced materials	❌ **Cannot cater to bespoke customer requirements:** Standardised product sale	✅ **Customized as per customer application needs:** we can engineer the product as per what you require

The Multi Core Hybrid Power technology is a **Breakthrough in Redundancy**. OptiPrime is the first genset series to integrate a multi cores, ensuring that even if one power source fails, the other continues operation.

- Seamless failover during power disruptions – Eliminates downtime risks.
- Parallel operation for higher efficiency – Load balancing across multiple power sources.
- Scalable architecture for modular expansion – Supports growing data center energy needs.

Fuel Efficiency & Total Cost of Ownership (TCO) benefits are significant. One of the biggest operating costs for data centers is fuel consumption in backup power solutions. OptiPrime significantly reduces fuel costs due to:

- Better fuel efficiency, especially at partial loads. Traditional gensets suffer at low load operation (most generator sets are designed to run at >70% load); OptiPrime's intelligent hybrid system optimizes fuel consumption.

- Opportunity to integrated Battery Energy Storage (BESS). This reduces diesel dependency by using stored energy first.
- Opportunity to perform waste heat recovery to power cooling solutions. This results in significant improvements in energy savings.

A comparison between OptiPrime and competition shows that OptiPrime reduces fuel consumption by up to 30-40% at typical load patterns, making it the more cost-effective long-term solution.

Compared to competitors, OptiPrime eliminates single points of failure, making it a superior choice for mission-critical facilities.

The OptiPrime Multi Core Power Systems portfolio

kVA Node	Fuel	Emission Norms	Comments	kVA Node	Fuel	Emission Norms	Comments
125 kVA	Diesel	CPCBIV+	Dual Core 4R810	1250 kVA	Diesel	CPCBIV+	Quad Core SL90
250 kVA	Diesel	CPCBIV+	Dual Core 41080	1500 kVA	Diesel	CPCBIV+	Dual Core DV12
320 kVA	Diesel	CPCBIV+	Dual Core 6K1080	2000 kVA	Diesel	CPCBIV+	Dual Core DV16
400 kVA	Diesel	CPCBIV+	Dual Core 6K1080	2000 kVA	Diesel	CPCBIV+	Quad Core PV6
500 kVA	Diesel	CPCBIV+	Dual Core 6K1080	2250 kVA	Diesel	Stack	Dual Core DV16
500 kVA HD	Diesel	CPCBIV+	Dual Core SL90	2500 kVA	Diesel	Stack	Dual Core DV16
640 kVA	Diesel	CPCBIV+	Dual Core SL90	2500 kVA	Diesel	Stack	Dual Core K12
1000 kVA	Diesel	CPCBIV+	Dual Core PV6	2500 kVA	Diesel	CPCBIV+	Quad Core DV10
1000 kVA	Diesel	CPCBIV+	Quad Core 6K	3000/3300 kVA	Diesel	Stack	Dual Core K12
1000 kVA	PNG	CPCBIV+	Dual Core DV12	3000 kVA	Diesel	CPCBIV+	Quad Core DV12
1000 kVA	PNG	CPCBIV+	Quad Core DV8	5000 kVA	Diesel	Stack	Quad Core DV16
2000 kVA	PNG	CPCBIV+	Quad Core DV12	5000 kVA	Diesel	Stack	Quad Core K12
1250 kVA	Diesel	CPCBIV+	Dual Core DV10	6000/6600 kVA	Diesel	Stack	Quad Core K12

The OptiPrime multi core power systems are bespoke engineering solutions that are designed to keep in mind the requirements of the customer site. The bespoke solution is completely turnkey and offers unmatched footprint along with noise attenuation.

1000 kVA Dual Core OptiPrime Power System -> A marvel of engineering

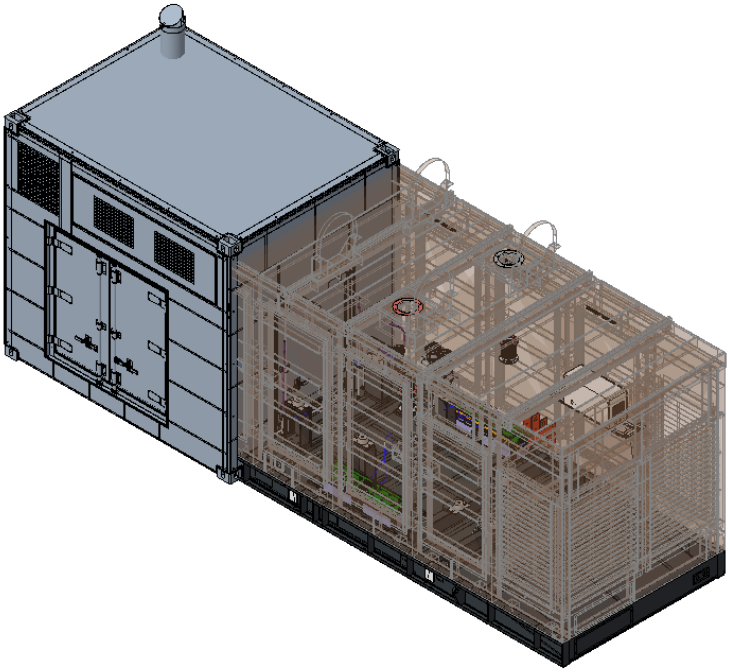


Figure 1: Comparison of OptiPrime 1000 kVA Dual Core Power System with a standard 1000 kVA Genset

Genset	Length (m)	Width (m)	Height (m)	Footprint (m^2)	Volume (m^3)
Cummins KTA38 (E)	8.0	3.0	3.0	24	72
KOEL DV16	7.8	2.3	2.71	17.9	48.7
1000kVA Optiprime	3.5	2.4	2.9	8.4	24.36

640 kVA Dual Core OptiPrime Power System -> For solving footprint challenges

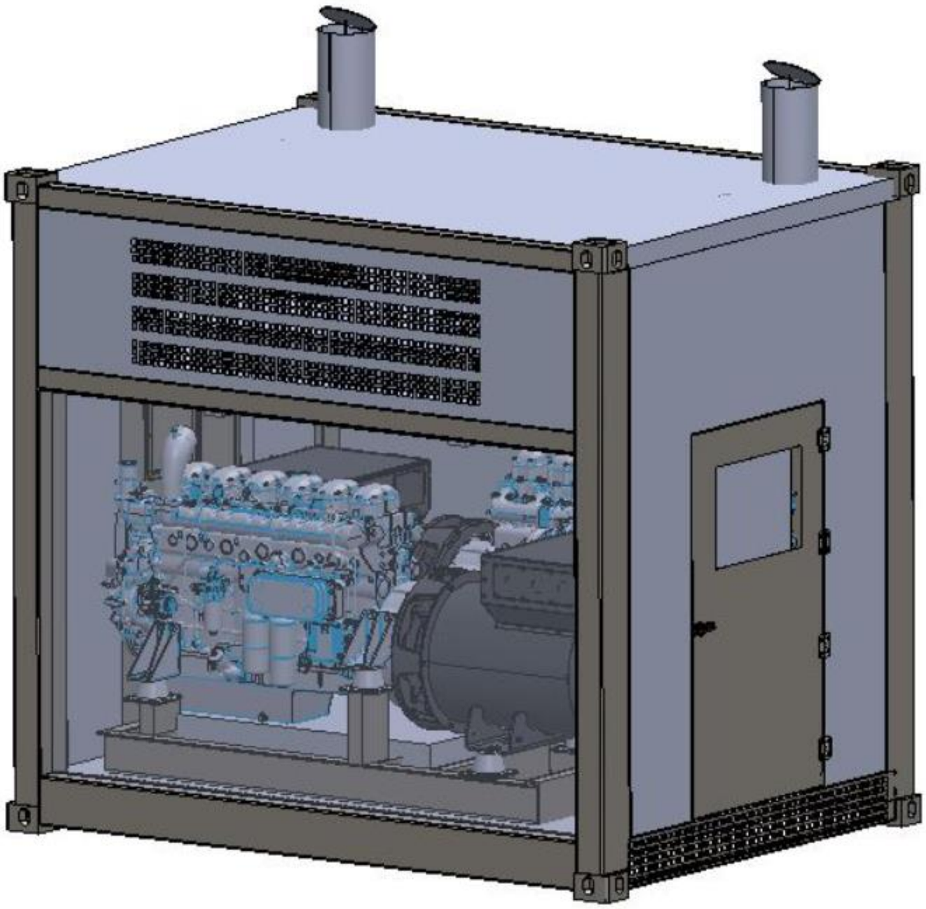


Figure 2: Comparison of 640 kVA OptiPrime Dual Core Power System with a standard genset

Genset	Length (m)	Width (m)	Height (m)	Footprint (m^2)	Volume (m^3)
Cummins QSK19	6.8	2.05	2.90	13.73	39.83
KOEL DV10	6.5	2.12	2.71	13.78	37.34
640 kVA Optiprime	2.5	2.4	1.7	6.0	10.2

2500 kVA Dual Core OptiPrime Power System -> Designed ground up for Data Centers

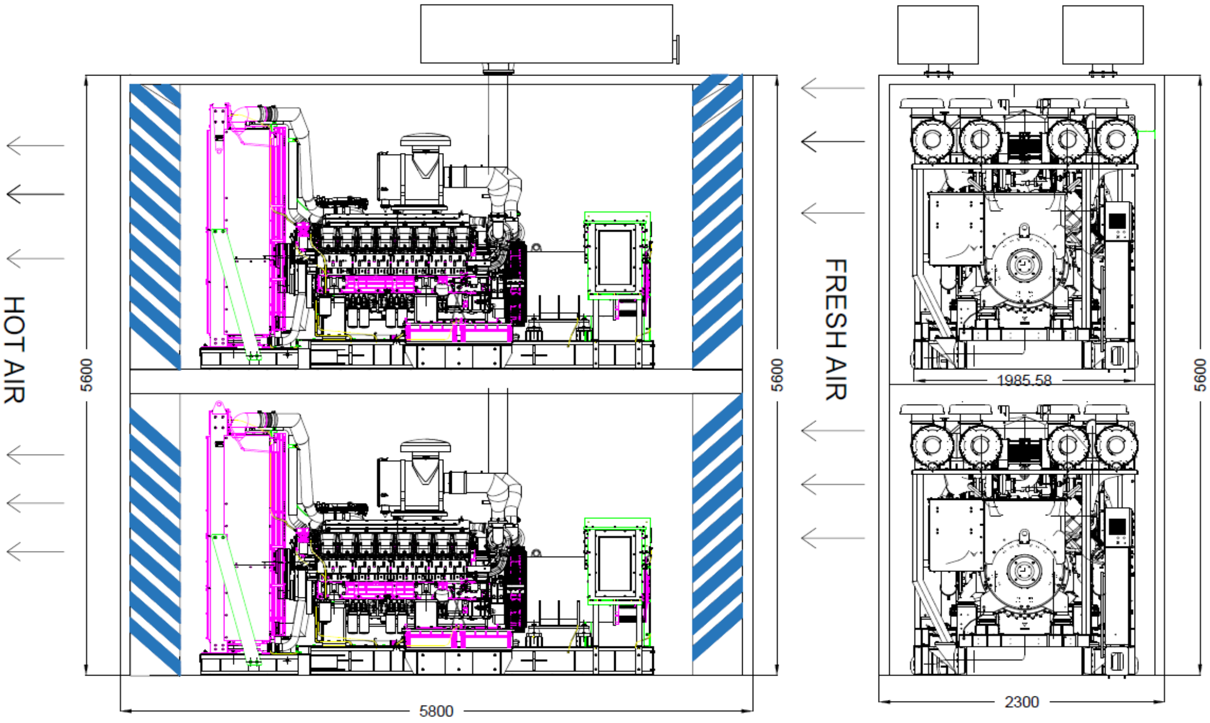


Figure 3: Industry leading footprint reduction for OptiPrime 2500 kVA Dual Core Power System

2500 kVA Genset	Type	Length (L)	Width (W)	Height (H)	Footprint (m2) LXW
KOEL 2500 kVA dual core OptiPrime	Specialised System	5800	2300	5400	13.34
Cummins 2500 kVA (QSK 60) Open DG	Open DG	6175	2286	2537	14.12
Baudouin 2500 kVA Open DG	Open DG	6900	2215	3181	15.28
Perkins 2500 kVA Stby (4016 61 TRG3) Open DG	Open DG	6000	2750	3600	16.5
CAT 2500 kVA Open DG	Open DG	6376	2286	2493	14.58
Cummins 2500 kVA (QSK 60) Enclosed with Canopy	Canopy	10450	3500	3800	36.58
Baudouin 2500 kVA Enclosed with Canopy	Canopy	12000	2350	2700	28.2

6600 kVA Quad Core OptiPrime Power System -> The ultimate solution for Data Centers

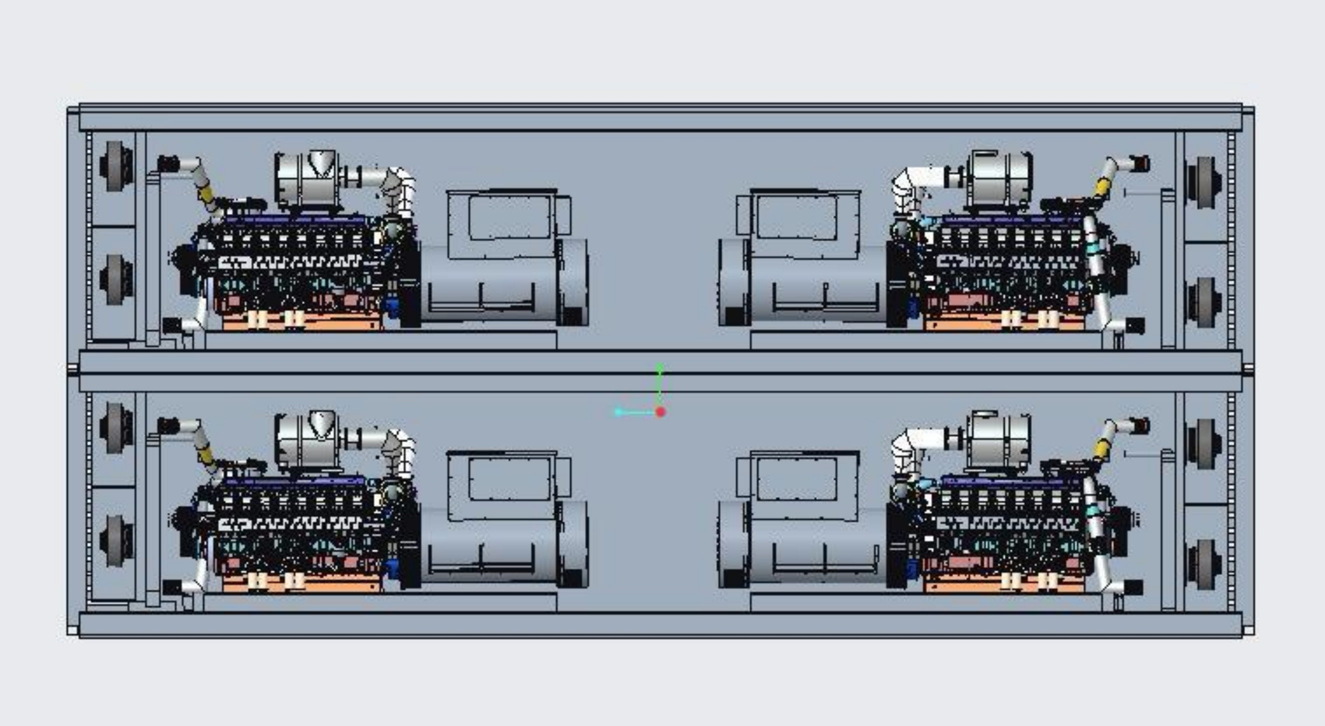


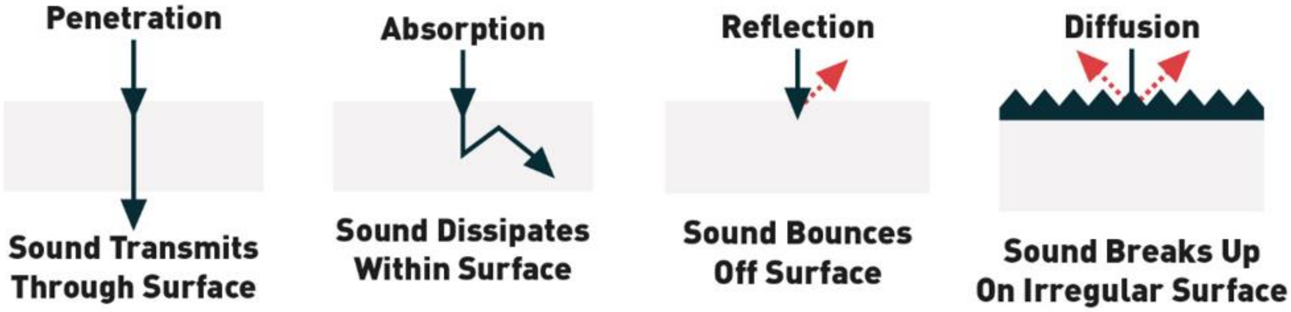
Figure 4: The Optiprime 6600 kVA Quad Core Power System

The 6600 kVA OptiPrime Quad Core DCC rated power system is another bespoke engineered solution for Data centers that have a significant footprint crunch. The Quad Core power system has a length of 40 feet and outperforms any genset in terms of fuel efficiency, footprint management and redundancy. It currently does not have any equivalent in the market.

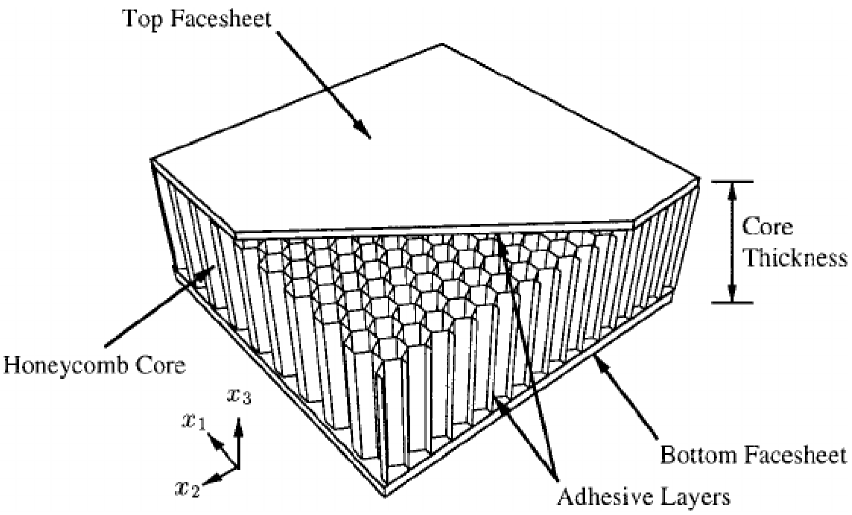
Unmatched Noise Attenuation

Sound waves can interact with surfaces in a variety of manners. Depending on the type of surface that a sound wave is striking, the results can differ. There are 4 ways in which a sound wave can interact with a surface. These include penetration, absorption, reflection and diffusion.

Our modern composite material for canopy construction comes with a host of practical and technical advantages over traditional metal sheets. These composite panels can reduce noise by combining different materials with varying densities and textures, allowing them to effectively absorb and dissipate sound energy across a wide range of frequencies, essentially "trapping" sound waves and preventing them from traveling further through a space; this is achieved by layering materials that act as both sound barriers and sound absorbers within a single panel.



Unmatched Fire Safety



We are leveraging materials from aerospace industry for ensuring fore safety for your data centers. The unmatched strength of honeycomb panels, particularly aluminium honeycomb panels is a defining characteristic that sets them apart as a superior choice for a wide array of installations and applications. The secret lies in their ingenious structural design. The hexagonal honeycomb core, often crafted from high-grade aluminium, creates a robust framework that distributes mechanical loads evenly across the panel’s surface. This design imparts exceptional strength and rigidity to the panels while keeping their weight remarkably low. In fact, the strength-to-weight ratio of aluminium honeycomb panels is unparalleled, making them stronger than many solid materials, such as steel or traditional aluminium, while being significantly lighter.

ThFR grade A2+, they offer excellent fire resistance. The honeycomb core's hexagonal design slows down the spread of fire, providing more time for evacuation ese panels are non-combustible and do not melt, ensuring safety in case of fire. With a high fire rating of and reducing damage. This makes them particularly useful in applications where weight reduction is crucial, such as in aerospace engineering, metro coaches and theatres. We are leveraging this technology for creating bespoke fire proof power solutions to ensure we derisk our customers.

Future Proofing your Data Centers

Future proofing Data centers via advanced Emissions Compliance & ESG Benefits: Sustainability is now a key consideration for data centers, with governments imposing stricter emission norms.

Our OptiPrime multi core power systems are designed to enable net zero targets for Data centers while ensuring improvement in power backup systems:

- Power Density: The multi core units of OptiPrime are amongst the most power dense units available in the industry.
- Emission Compliance: Global emission compliances even >800 KW. Our OptiPrime range of generators are available up to 3000 kVA with after treatment systems. We can provide units that are compliant with CPCB IV+ (India), EURO V (Europe), and Tier IV Final (USA) standards. Up to 50% reduction in CO_2 and NOx emissions compared to traditional gensets
- Alternate Fuels: Available in Natural Gas and alternate fuels. Our OptiPrime range is available for up to 2000 kVA in Natural Gas. Details of alternate fuels such as Ethanol, Methanol, Hydrogen, Dual Fuels, Hythane etc can be provided upon request and study

By lowering carbon footprints, OptiPrime allows data centers to meet Net Zero commitments and qualify for ESG funding.

Seamless Integration with Data Center Infrastructure.

OptiPrime supports fast paralleling with data center Building Management Systems (BMS), Data Center Management Systems (DCMS), and Energy Management Systems (EMS).

- Remote monitoring & AI-driven predictive maintenance
- Fast synchronization with existing UPS & switchgear
- Customized enclosure solutions for different operational needs

Competitor Comparison: Cummins gensets require separate parallel control modules, increasing installation complexity. OptiPrime integrates control features within the standard package, reducing commissioning time.

The OptiPrime Controller

Managing four diesel generator sets (gensets) in parallel with a single centralized controller (and no individual GCUs at each generator) requires robust architecture. The central controller handles all synchronization, load sharing, and protection functions for the generators, communicating with engine actuators and sensors via a Controller Area Network (CAN) bus. This setup eliminates per-generator control units (typically each genset would have a separate Genset Control Unit or a GCU) in favor of one “master” control system, which can simplify coordination but demands advanced control strategies for optimal performance. The single biggest goal of the OptiPrime Controller is to ensure that the system operates like a single “Genset” and the overall system is optimized for fuel consumption and load management. The idea is to ensure that no genset need to run below 75% load. So, for instance if the overall load is 6000 kVA and we have our OptiPrime 6600 kVA Quad Core genset running, then each of the core/power units should start together with minimum time and depending on the load, the OptiPrime controller should switch off the units that are not required. For example, if the overall load reduces to 3000 kVA, then only 2 units need to run and balance 2 need to switch off. If the overall load reduces to 1200 kVA, then only one power unit/core needs to run and 3 must switch off. Key goals are efficient load sharing among the gensets, fast and stable synchronization, fault tolerance (to avoid single-point failures), and AI based adaptive control that responds to changing load conditions. Below, we describe the centralized control architecture and outline state-of-the-art control strategies (using modern algorithms and communication practices) to meet these goals.

Centralized genset control architecture: A single master controller (analogous to a Microgrid Central Controller in concept) oversees multiple generator units (G). The controller communicates with generator subsystems (engine governors, AVRs, etc.) over a CAN bus. This centralized scheme replaces individual on-board GCUs with one control unit coordinating all gensets. Each generator's breaker, voltage regulator, and engine governor are managed by commands from the central controller. Feedback (e.g. generator voltage, frequency, kW output) is sent to the controller via CAN for closed-loop control.

Centralized Control System Architecture (CAN-Based)

In this architecture, a single controller performs roles typically handled by individual Generator Control Units. It interfaces with each genset's engine governor and voltage regulator through a common CAN bus network. The CAN bus allows the controller to send setpoints (e.g. desired throttle/fuel input for engine speed, or excitation for voltage) and to read back measurements like generator power, frequency, and voltage from each unit. Modern engines and digital AVRs often support the SAE J1939 protocol over CAN, which the central controller can leverage for command and telemetry . The elimination of individual GCUs means the central unit runs all control loops (speed/frequency control, voltage regulation, etc.) for each generator. In practice, each engine's Electronic Control Module (ECM) or governor may handle low-level actuation but receives its reference from the central controller.

CAN Communication: The CAN bus serves as a reliable high-speed link between the central controller and gensets. It significantly reduces wiring complexity by replacing many analog signals with a single two-wire network. CAN is a multi-master bus with message prioritization – critical control messages can be given high priority IDs to get bus access immediately, without interrupting lower-priority traffic. This ensures timely commands for synchronization or load adjustments. The bus is also robust against electrical noise and interference, which is important in the electrically noisy environment of generators. Best practices for CAN in genset control include:

- **Using standard protocols** (like J1939 or CAN open) to define message structure for engine speed, voltage setpoints, power measurements, etc., ensuring interoperability.
- **Proper bus topology** (daisy-chained nodes with 120Ω terminators at both ends of the CAN network) and shielded twisted-pair cabling to minimize noise.
- **Periodic heartbeat messages** or node monitoring to detect any loss of communication. If a generator's ECU fails to respond, the central controller can raise an alarm or isolate that unit.
- **Arbitration and timing:** Assigning higher priority to fast control loops (e.g. sync and load share commands) and lower priority to non-critical data (e.g. diagnostics) so that real-time control is maintained. Using the CAN message arbitration, the system naturally handles simultaneous transmissions by prioritizing lower ID numbers (higher priority).

Using CAN for load sharing and sync signals (instead of analog load-share lines) has become common in modern systems. Digital communications like CAN are less susceptible to drift and noise than analog methods. The only interface needed between gensets is the data on the CAN bus – no direct analog cross-current or speed-droop wiring between generators, since the central controller digitally coordinates their outputs. Each generator's controller (in this case, the central unit modeling each generator) calculates the generator's power output and shares it over CAN so that the total system load can be distributed evenly.

Efficient Load Sharing and Fast Synchronization

Active Load Sharing: In a parallel generator system, load sharing means each genset carries its proportionate share of the total load. Traditionally, this is achieved with droop or isochronous governors on separate units. Droop control is the conventional method – each generator's frequency setpoint drops slightly as load increases, inherently balancing load (the unit with more capacity takes more load until frequencies equalize). Droop is simple and requires no communication (each unit adjusts based on local frequency deviation). However, in a centralized architecture with CAN comms, more precise isochronous sharing is feasible. The central controller can run an Isochronous Load Sharing (ILS) algorithm for both real power (kW) and reactive power (kVAR). In isochronous mode, the controller keeps all generators at the same frequency and actively controls each engine's fuel input and each AVR's excitation so that every unit supplies the required percentage of load. For example, if the system load is 60% of total capacity and four identical gensets are online, the controller will adjust outputs, so the first genset works at 100% load (25% of system load), the second genset works at 100% load (another 25% of system load) and the third genset runs at 10% load. each. It does this by calculating the total system load and each generator's share:

- The controller reads each generator's kW and kVAR output over CAN.
- It sums the outputs to get total load and computes the desired per-unit load (e.g. this could be set at each unit has to achieve 80% load before the next genset switches "On". In other cases, we may also decide to distribute the loads amongst each of the DG sets with 25% each for equal sharing).
- It compares each unit's actual percentage load to the target and biases the engine throttle or AVR setpoint of each genset accordingly. For instance, if Gen#1 is carrying less than its share, the controller raises its fuel command and simultaneously lowers commands to any unit exceeding its share. This closed-loop regulation drives the individual loads toward equal percentages.

This active load sharing approach maintains isochronous frequency (the bus frequency stays at nominal 50/60 Hz for all units) while preventing one generator from hogging the load. Communication latency on CAN is low (on the order of milliseconds), so the controller can rapidly correct load imbalances. Each adjustment is broadcast to the gensets almost in real time, achieving tight coordination. Reactive power sharing is handled similarly by adjusting voltage/excitation to balance kVAR. This centralized isochronous control is an advanced strategy compared to basic droop, since it can eliminate steady-state frequency error and share load more exactly, at the cost of requiring the central supervisory control.

Fast Synchronization: Before a generator can be paralleled to the others (or to a live bus), it must be synchronized – matching voltage, frequency, and phase. The central controller performs automatic synchronization of each incoming genset to the bus. Without individual GCUs, the central unit uses its measurements (or those from the generator's voltage sensors via CAN) to determine the phase angle difference and frequency difference between the generator and the bus. It then issues commands to adjust the generator speed (and possibly excitation) to swiftly align these parameters.

Modern digital synchronizers can use advanced techniques to minimize synchronization time:

- **Dynamic frequency adjustment:** The controller might momentarily raise or lower the engine speed setpoint to quickly bring the generator into phase with the bus (this is often called slip synchronization). By slightly leading the bus frequency then dropping to match, the generator can "catch" the right phase instant for breaker closure, reducing wait time.
- **Phase angle prediction:** With fast communication, the controller can predict the closing point by measuring the rate of change of phase difference and send a close command at the precise moment alignment will occur. Using synchrophasor measurements (high-precision angle sensors) is an emerging technique to maintain "perpetual synchronization" by continuously aligning phase via communication, though this typically requires PMU hardware.
- **Internal synchronizer algorithms:** The central controller likely implements an internal digital synchronizer function (replacing any external synchroscope or analog sync relay). This digital sync checks voltage magnitude match and phase within a tight window (often <5 electrical degrees difference) before initiating breaker closure. Because the central unit has direct control of engine speed, it can actively drive the difference to zero rather than waiting passively.

The result is faster synchronization when bringing generators online. Instead of each unit slowly drifting into sync on its own, the master control actively drives them into sync. Some research even applies optimization algorithms (e.g. metaheuristic tuning) to the synchronization controller to speed it up. For example, one study tuned a sync controller using a hybrid killer-whale and grasshopper optimization algorithm to minimize phase and voltage differences quickly. In practice, a well-tuned PID loop on speed, combined with communication-based phase monitoring, allows synchronizing a generator in a few seconds. Fast sync means generators can be added or removed with minimal disturbance, which is crucial for handling rapid load changes or backup power restoration.

During parallel operation, the central controller keeps all online gensets tightly synchronized. Any tendency of one unit to drift in speed is immediately corrected via CAN commands. By maintaining isochronous control, the bus frequency is held constant (within tight deadband) and all machines remain in phase once paralleled. This prevents circulating currents or torque oscillations. In contrast, purely droop-based systems allow slight frequency deviations and rely on droop characteristics to share load; the centralized system avoids that compromise by direct control.

Microcontroller System Design

The genset controller is built around a robust microcontroller unit (MCU) that serves as the brain of the system. This MCU is selected for adequate performance in real-time control and harsh environment operation:

Processor Selection: A high-reliability 32-bit microcontroller or DSP is typically used for example, an ARM Cortex-M or a specialized automotive-grade MCU capable of fast ADC sampling and interrupt handling for engine control. The processor must handle multiple control loops concurrently (speed, voltage, phase sync) and communication stacks (CAN, Modbus, etc.). It often includes a hardware multiplier/FPU for control algorithms and sufficient I/O for all sensors/actuators. Temperature and EMI tolerance are crucial due to the electrical noise in generator environments.

Memory (Flash, RAM, EEPROM): The controllers firmware and control algorithms reside in non-volatile flash memory, allowing program updates and retention of code even when power is off. Firmware is often field-upgradable via a port (e.g. RS-232 or USB) to improve algorithms or add features. Sufficient on-chip RAM is needed for real-time data (sensor readings, state variables for PID/AI calculations) and buffering communications. Configuration settings, calibration data, and fault logs are stored in EEPROM or battery-backed RAM so that they persist across reboots. For instance, the Basler DGC controllers store all programming setpoints in non-volatile memory and use RAM to log metering data and events. The memory architecture ensures that on power-up or reset, the MCU can safely resume configured operation.

Peripheral Interfaces: A variety of built-in peripherals on the MCU are utilized to connect with the genset and external systems. Analog-to-digital converters (ADC) read analog signals: generator voltages, currents (via CTs/PTs after conditioning), engine sensor voltages (oil pressure, temperature, fuel level). These inputs are filtered and scaled to levels where the MCU can digitize accurately. Timers/counters capture engine speed from pickups or frequency measurement of AC output. On the output side, digital/PWM outputs control actuators like the fuel solenoid or throttle motor and excitation circuits. Communication peripherals include UARTs (for RS-232/485 serial links), CAN controller (for J1939 or CAN open network to engine ECU and other controllers), SPI/IÂ²C (to interface with external ADCs, expanders, or sensors modules if needed). The MCU is essentially a System-on-Chip with CPU, memory, and I/O it coordinates all these interfaces to implement the control logic. For example, it might use an SPI ADC to get high-resolution voltage readings or IÂ²C to communicate with a real-time clock or an external EEPROM. All peripheral interactions are managed in firmware, which is structured to handle the time-critical tasks (e.g. ADC sampling and PID loop updates synchronized to the power cycle) with high priority

CAN Bus Topology

A Controller Area Network (CAN) bus links the genset controllers (and possibly engine ECUs or an external supervisor). The diagram shows a daisy-chained CAN network (blue line) connecting all RGCP controllers. Key design points of this network:

Node Addresses: Each device on the CAN bus has a unique identifier or address so that their messages can be distinguished. Typically, one sets a CAN ID for each genset controller (either via DIP switches, software configuration, or auto-addressing). For instance, in a system of multiple generators, controllers might use an address based on their generator number. The network protocol (often SAE J1939 or a proprietary scheme) defines how load share info, breaker status, and sync signals are encoded in CAN messages. Address management ensures no conflicts and that messages like generator status, load, and commands reach all nodes. In practice, one controller may be designated as the lead unit broadcasting a reference, and others respond accordingly, all via CAN frames.

Bus Wiring and Termination: The CAN bus is wired as a single twisted-pair trunk connecting all controllers in parallel (a multi-drop bus). To maintain signal integrity, 120 termination resistors are placed at both ends of the CAN bus. This matches the cable impedance and prevents reflections. Intermediate nodes (controllers in the middle of the chain) do not add terminators (or use high-value resistors if necessary). For example, if you have five controller's daisy-chained, the first and last unit enable their 120 terminators, yielding ~60 measured across CANH-CANL. The CAN wiring is run in a bus topology (no star connections) to avoid signal reflections. Typically, shielded twisted pair cable is used for noise immunity, and maximum stub length to any node is kept short. Ensuring proper termination and cable routing is vital for reliable high-speed communication on the genset network.

Redundant Communication Bus: For high availability, the design can include a backup CAN bus in parallel. Dual CAN networks (often called CAN A and CAN B) allow operation to continue even if one bus is damaged or fails. Each controller then has two CAN transceivers connected to two sets of wiring. Under normal conditions, the primary bus carries data; if an error or loss of bus is detected, the system switches to the secondary bus. This is a common approach in critical power systems a one primary and one secondary CAN bus, used in case of failure of the primary. The diagram indicates this with the label CAN or Fiber (redundant), some systems even use a different medium (fiber-optic ring) for the redundant path to add isolation. The redundancy ensures that a single cable fault won't isolate the controllers. Additionally, the communication protocol might include heartbeat messages so that if a controller itself fails or stops communicating, the others can alarm and possibly adjust (e.g. dropping that unit from load share).

Fault Tolerance and Redundancy Measures

A single-controller system must be designed with fault tolerance in mind, since the controller is a critical single point of control. The controller's logic continuously monitors for faults (engine alarms, generator electrical faults, communication errors). On detecting an issue, it takes protective action e.g. shutting down the engine, opening the breaker, or isolating a failed unit to maintain system stability. Each controller has a built-in watchdog timer and self-diagnostic routines; if the software hangs or a severe fault is detected, the watchdog resets the microcontroller to a safe state. In a networked system, if the central coordination fails (e.g. loss of CAN communication or a master controller fault), the system falls back to fail-safe modes. Failover mechanisms include automatic transfer of control to a hot-standby controller or reverting to decentralized control. For example, the DEIF AGC system allows redundant master controllers if the active one fails, a standby immediately takes over to keep generators in control. Additionally, generators may revert to droop mode or analog load sharing lines as a backup, ensuring continued power sharing without communications. This droop fallback means each generator's governor will slightly drop speed with increasing load, inherently sharing load without a communications link a proven fail-safe so that no single controller fault can bring down the entire plant

Several measures can be made available to ensure reliability:

- **Redundant Controller (Hot-Standby):** For high availability installations, a second identical controller can be set up in parallel as a hot-standby. This backup controller monitors the primary and instantly takes over control if the primary fails or goes offline. The failover should be automatic and bump less – the secondary picks up the CAN communications and continues sending commands with minimal disruption. Modern generator control systems support redundant configurations where each genset's interface connects to both controllers, and a "watchdog" logic switches to the backup on fault. This prevents a single hardware failure from blacking out all generators. At minimum, important safety controls should fail over to a backup; for example, an independent analog droop governor could act as a fallback if digital control is lost (see next point).

- **Fail-Safe Local Control:** Even without full GCUs, each generator should have basic protective and control circuits locally. For instance, the engine ECU typically has an internal overspeed shutdown and possibly a droop mode that can engage if external commands are lost. If the CAN bus communication fails or the central controller stops issuing setpoints, each generator's governor can revert to a default speed setting (e.g. 60 Hz droop mode) to prevent runaway. They would no longer share load perfectly, but this fail-safe mode keeps the generators running in island operation until an operator intervenes. Similarly, each AVR could fall back to maintaining voltage at a preset value with droop to avoid circulating reactive currents. The system design should incorporate loss-of-comms detection – if no CAN messages from the master for a defined timeout, each genset switches to standalone control to carry the load (or trips offline if it cannot). This ensures the power supply isn't abruptly cut due to a controller fault; instead, it degrades gracefully.

- **Protective Functions:** The centralized controller implements protection like over/under-frequency, over-current, differential protection of the generators, etc. If it detects a generator fault (e.g. one unit's frequency or voltage deviating beyond a threshold), it can trip that unit's breaker and isolate it. It then redistributes the load to the remaining units. For fault tolerance, critical protections (overspeed, overvoltage) are often hardwired as well, not solely reliant on software. The controller should also send alarm data over CAN (or to a SCADA system) in case of sensor failures, so maintenance can be done proactively.

- **Fault Detection:** Advanced monitoring can be incorporated. The controller can continuously compare commanded vs actual output of each genset. If a generator is unable to follow commands (e.g. its power output isn't increasing despite fuel command – indicating a governor issue or mechanical problem), the controller flags this and possibly unloads that generator gradually to prevent instability. Vibration or performance data from engine ECUs (often available via J1939) can feed into an AI diagnostic system to predict failures. In a CAN-based system, each node's status (error counters, etc.) can be monitored – a rising error count might indicate wiring issues, prompting a preventive check.

- **Network Redundancy:** For very critical systems, the CAN bus itself could be duplicated (dual CAN networks) so that a backup communication path exists if one bus is damaged. Alternatively, using a ring topology with Ethernet (if the controllers support it) could be an option for redundancies, but typically CAN in a single bus is very robust if properly installed. Ensuring all connectors are secure and perhaps having a "bus health" diagnostic in the controller (which CAN inherently provides via error frames) helps maintain communication reliability.

In essence, fault tolerance is achieved by a combination of hardware redundancy, fail-safe defaults, and intelligent fault-handling algorithms. As an example of a robust design: a data center paralleling system might use dual redundant PLC controllers in hot standby, and each genset's ECM has a backup governor mode. If the active controller fails, the secondary takes over within a cycle and continues controlling all four gensets, and operators are alerted to the failure without losing power. This kind of design is recommended whenever uninterrupted power is critical.

Protection Circuits and Fail-Safes

Protection and safety are critical in genset control design. The system includes both software logic and hardware circuits to protect the generators and connected loads:

Breaker Control & Synchronization: The controller manages the generator circuit breaker (GCB) and often a mains breaker (MCB or tie breakers) through relay outputs. Before closing a breaker, the controllers' sync-check function ensures phase, frequency, and voltage match within set limits. Once synchronized, the controller sends a close command to the breaker coil, connecting the generator to the bus. Conversely, the breaker will open during shutdown, fault conditions, or load shedding events. The breaker control outputs are interlocked with protective conditions e.g. inhibit close if voltage mismatch is detected, or trip open immediately if a major fault occurs (such as generator over-frequency or bus fault). Close-before-excitation is another feature (closing the breaker and then ramping up excitation) used in some systems to limit inrush, coordinated by the controller. In the diagram, each GCB and the MCB are shown controlled by the RGCP this ensures the power distribution (generator-to-bus connection) is only made when safe and desired.

Overcurrent and Overvoltage Protection: The microcontroller continuously monitors generator output currents and voltages (via sensing CTs/PTs). If an overload or short-circuit occurs, the controller will initiate a trip: opening the generators breaker to protect the alternator and downstream equipment. Likewise, if output voltage exceeds thresholds (due to regulator failure or load rejection), the controller can trip the field or open the breaker to protect load devices from over-voltage. These functions mimic a traditional protective relay. Often, the controller has settings for over-current (with time delays or inverse curves), instantaneous short-circuit, over/under-voltage, over/under-frequency, etc., acting as a protective relay and sending alarms. For example, an overload might first trigger an alarm or load shedding (if multiple gensets are running, it might start another unit or shed non-critical loads), and if thresholds are exceeded, the breaker is opened. There are usually hardware fail-safe cutouts as well such as an independent circuit that will trip the breaker if current goes extremely high and perhaps a fuse or circuit breaker on the excitation circuit for over-excitation. By integrating these protections, the controller prevents equipment damage, with the MCUs logic executing trips in milliseconds when needed.

Fail-Safe Mechanisms (Droop & Backup Control): In addition to redundancy in communications, each genset has analog fallbacks to ensure stability if digital control fails. A common fail-safe is speed droop governance: if the centralized load sharing signals are lost, the engine governors revert to droop mode (slight frequency decrease with load) so that multiple generators can still share load automatically . This prevents a scenario where loss of communication could cause generators to fight each other or one unit to carry everything. Some systems include dedicated load share lines or secondary controllers; for instance, legacy load sharing modules or droop CTs that ensure proportional load sharing independent of the main controller. Watchdog relays are another hardware fail-safe the microcontroller toggles a heartbeat output regularly, and if it fails, a relay can drop out to trigger alarms or put the genset in a safe state (like returning engine to base speed droop). The diagrams note of a droop biasing and the presence of a PLC in the loop indicate that even if the central RGCP unit fails, the generators (with their own governors/AVR) will continue to run at droop settings, preventing total loss of power. Mechanical fail-safes (e.g. overspeed valve, coolant safety cutout) are also present outside the electronic controller. All these layers ensure the system is fault-tolerant, shutting down or isolating only the affected parts while keeping the overall power supply as stable as possible.

HMI and SCADA Integration

The genset controller provides interfaces for both local operators and remote supervisory systems (SCADA):

Local HMI (Human-Machine Interface): Each controller typically has a front-panel display and controls or is connected to a dedicated HMI panel. This may include an LCD/OLED screen showing engine parameters, generator volts/amps, alarms, etc., along with push buttons or a touchscreen for control (start/stop, breaker close, mode select). The HMI is designed for intuitive operation so that an on-site technician can easily monitor status and acknowledge alarms. LED indicators for statuses (running, alarm, breaker closed) and physical emergency stop buttons are also part of the interface. In the architecture, the front panel HMI is often driven by the same microcontroller it reads user inputs and displays feedback. Some systems offer a remote display unit as shown in the block diagram (RDP-110 in the earlier Basler excerpt) which connects via a communication link to the main controller. This allows mounting a display on a control room panel while the controller itself may be on the genset. The HMI provides local access to configure settings (e.g. adjusting the PID gains or protection setpoints) through menus, usually protected by password levels.

SCADA/Remote Monitoring Interfaces: For integration into a supervisory control and data acquisition system, the controller includes communication modules for remote access. Common protocols are Modbus RTU/TCP, CAN (J1939 for engine data to the plant PLC), or even SNMP/Web interfaces for modern units. In our design, the controllers can connect to a SCADA or plant PLC via a serial RS-485 (Modbus) or Ethernet port. For example, a Modbus TCP/IP Ethernet module might continuously stream generator data (voltages, power, breaker status, engine metrics) to a SCADA PC. Operators at the central control room can then monitor and send commands (e.g. start/stop or load requests) remotely. The diagram shows a SCADA bus connecting to the controllers, and the RGCP-3400 example explicitly allows the whole system to be monitored via Modbus/CAN by a remote panel or SCADA software. Customers could monitor the whole system through the Modbus/CAN communication interface or use a remote-control panel for mode selection, data monitoring, alarm reset, etc. Additionally, newer controllers support IoT connectivity: built-in 4G/cellular or Wi-Fi modules to send data to cloud monitoring platforms. This enables predictive maintenance alerts or fleet management of many generator sites.

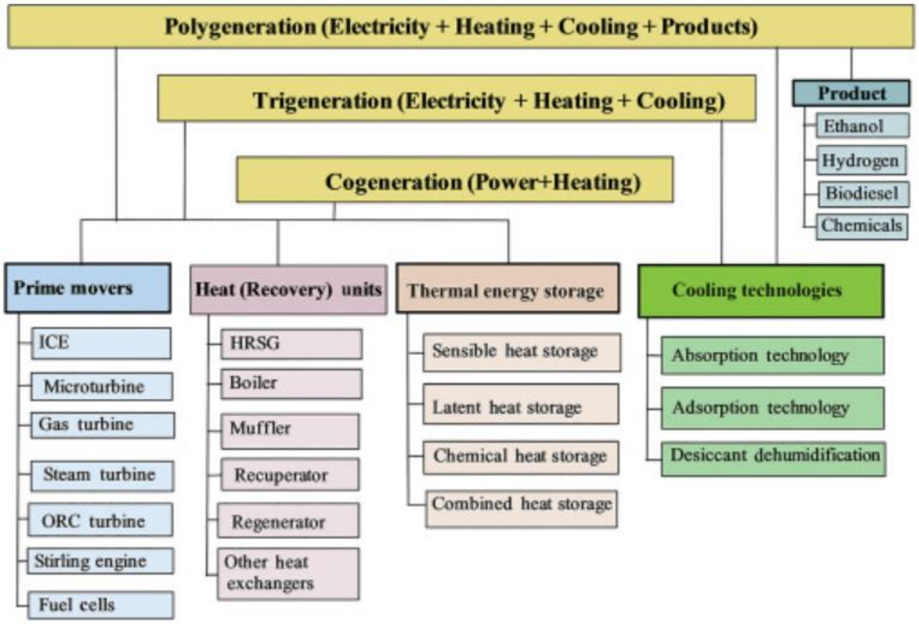
Potential strategies for enabling Net Zero for Data Centers

- Waste Heat Recovery Systems (WHRS): Exhaust Gas Heat Exchangers: Capture heat from exhaust gases to produce hot water or steam.
- Exhaust Gas Boilers (EGB): Use exhaust gases to generate steam, which can be used in industrial processes.
- Combined Heat and Power (CHP) / Cogeneration: Heat Exchangers for Water Heating: Extract heat from exhaust gases to provide hot water for industrial or residential use.
- Steam or Hot Air for Process Heating: Utilize recovered heat for drying, heating, or other industrial applications.

- Organic Rankine Cycle (ORC) Systems: Converts waste heat into additional electrical power using a working fluid with a lower boiling point than water. Increases overall system efficiency without additional fuel consumption.
- Thermoelectric Generators (TEGs): Utilize thermoelectric materials to directly convert heat from exhaust gases into electricity. Useful in remote areas where additional electrical generation is needed.
- Turbochargers with Heat Recovery: Improve combustion efficiency by using waste heat to drive turbochargers, increasing air intake pressure and fuel combustion efficiency.
- Absorption Chillers for Cooling Applications: Convert excess heat into cooling energy for air conditioning or refrigeration using an absorption chiller.
- Exhaust Gas Recirculation (EGR) with Heat Recovery: Recirculate a portion of the exhaust gas to reduce NOx emissions while recovering heat for preheating intake air.
- Supercritical CO_2 (sCO_2) Power Cycles: Uses high-temperature exhaust gases to drive a supercritical CO_2 cycle, enhancing power generation efficiency.

Polygeneration & Trigeneration Systems

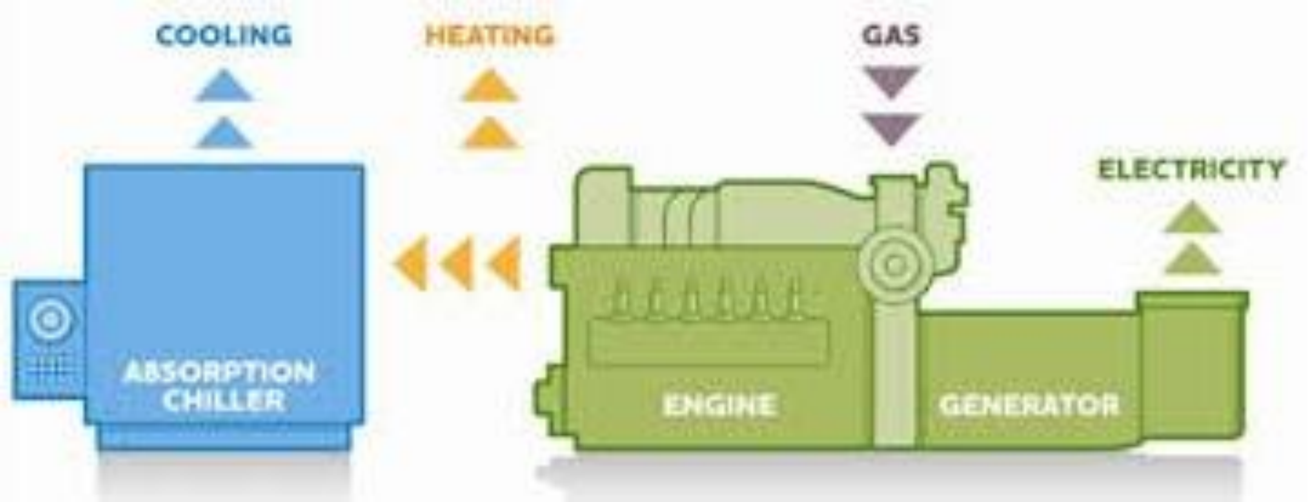
In polygeneration or multigeneration systems, in addition to the generation of power, cooling and heating, a few more energetic processes, such as production of chemicals,



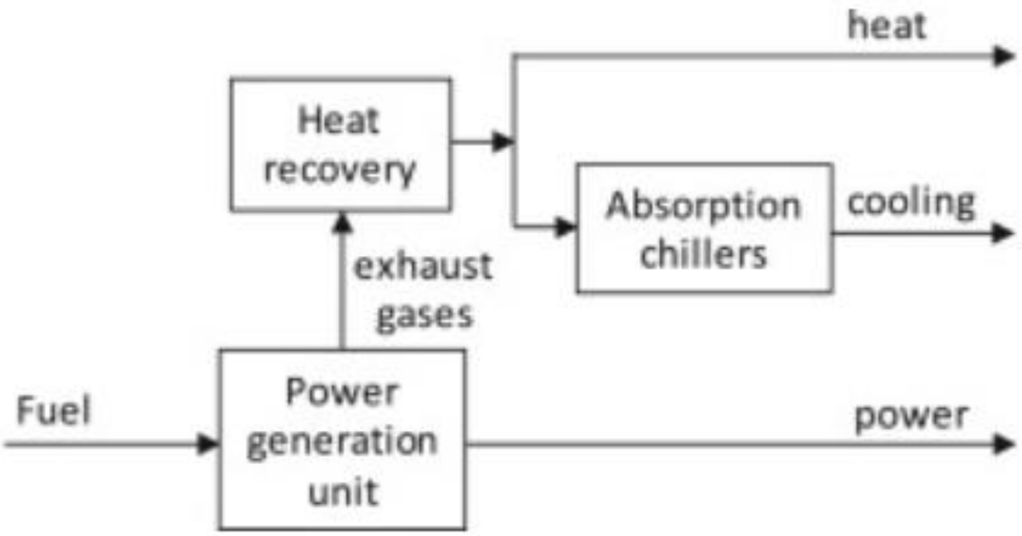
hydrogen, ethanol, biodiesel, fertilizers, and drinking water, are possible. Polygeneration system can be fueled by microgrids supported by renewable sources (geothermal, solar, biomass, wind and hydro), and fossil fuels (natural gas, coal, hydrogen, etc.) or by hybrid technologies.

Cogeneration is the simultaneous production of electricity and useful heat by using a single fuel source. During power production, the wasted heat can be recovered to provide process heat or to be delivered as a heat source for, e.g., hot water production for district heating and/or domestic use. Trigeneration or combined cooling, heat and power system (CCHP) is one step ahead of cogeneration since it aims the simultaneous generation of electricity, useful heating and cooling from a single fuel source. CCHP systems exploit the synergies between cooling, heat and power resulting in significant energy and CO2 emissions savings compared with isolated generation of cooling, heat and power. In addition to the heat processes, waste heat is used to produce cooling either by thermally driven heat pumps or desiccant systems.

Figure below shows a simplified scheme of a CCHP trigeneration system.

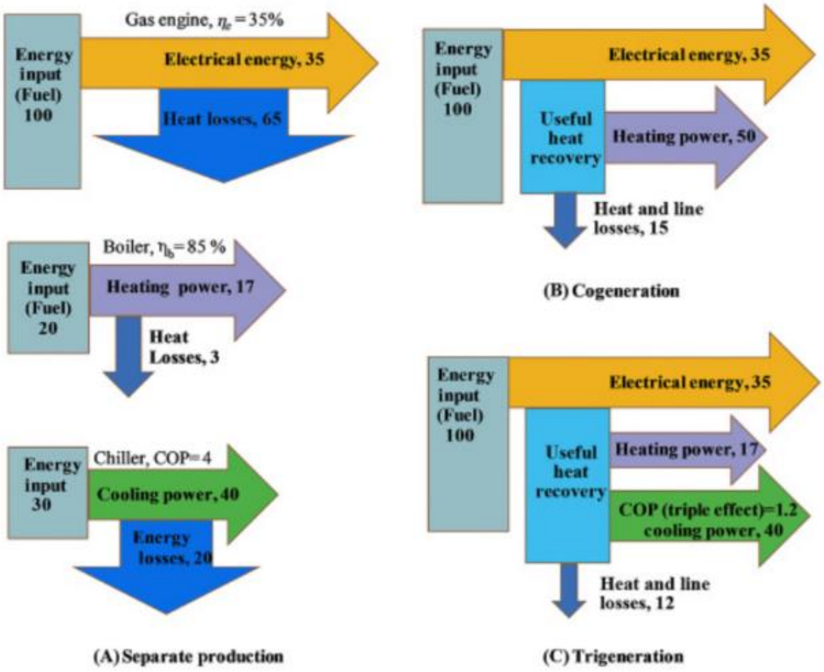


In 'separate production' (SP), the electricity is delivered from the local electrical grid, the cooling from electrical chiller and the gas boiler provides thermal energy. Cogeneration or CHP production is the simultaneous generation of electricity and useful heat, from a single fuel source. Trigeneration or CCHP refers to the simultaneous generation of electricity, useful heating and cooling from a single fuel source. The level of specific emissions (i.e. emissions per unit of useful energy produced) from co- and trigeneration systems is lower than those with conventional systems. In addition, trigeneration systems attain higher overall efficiencies than separate production, or cogeneration.



A typical trigeneration (CCHP) system consists of five main components: the prime mover, electricity generator, heat-recovery system, thermally activated equipment and the management and control system. Trigeneration systems vary from site to site, with diverse prime movers, cooling options, connecting forms, rated size ranges, heat-to-power rates, user demand limitations and similar characteristics.

Figure shows the comparison of typical (1) SP of energy; (2) cogeneration and (3) trigeneration. In SP, the total energy input for electricity, heat production and cold production is 150 units. The losses have been minimized in cogeneration and trigeneration. In trigeneration, the same outputs are produced at a reduced input of only 100 units.



(A) Separate production

(B) Cogeneration

(C) Trigeneration

Introducing OptiPrime Trigeneration Series: Integrated solution for the Green Data Center

The OptiPrime Trigeneration System is designed to provide simultaneous electricity, heating, and cooling using a single fuel source. It integrates:

- Kirloskar OptiPrime Diesel Gensets – High-efficiency power generation.
- Waste Heat Recovery System – Captures exhaust and cooling system heat.
- Kirloskar Absorption Chillers – Converts waste heat into useful cooling.
- Advanced Control Systems – AI-driven energy optimization.

This integration maximizes fuel utilization and achieves efficiencies exceeding between 65% to 85%, compared to conventional 42-45% efficiency diesel gensets. Integrating chillers with diesel generators can improve overall system efficiency by utilizing waste heat for cooling. This setup is particularly useful in data centers, hospitals, hotels, and industrial plants, where cooling demand is high. Chiller cycles are integrated within diesel gensets in two main ways:

1.1. Absorption Chillers (Heat-Driven Cooling): Best for: Large-scale cooling applications using waste heat. Efficiency Improvement: Reduces fuel consumption by up to 30%.

- Using waste heat from generator exhaust or cooling water to drive an absorption cooling cycle.
- Operates with a heat exchanger, an absorption cycle (lithium bromide-water or ammonia-water), and a cooling tower.
- Provides chilled water for HVAC, refrigeration, or process cooling.

Implementation Steps:

- Install a heat exchanger on the exhaust system to capture waste heat.
- Use the heat to drive an absorption chiller.
- Distribute chilled water to air conditioning or process cooling systems.

Example Applications:

- Data Centers → Cooling IT equipment with chilled water.
- Hospitals & Hotels → Air conditioning and refrigeration.
- Manufacturing Plants → Cooling machinery or chemical processes.

1.2. Compression Chillers (Electric-Driven Cooling): Best for: Cooling when generator power output is high. Efficiency Improvement: Reduces peak load on utility power supply.

- Uses electric power from the diesel generator to run a conventional vapor compression chiller.
- Works efficiently when the genset is oversized or when cooling demand matches power generation.

Implementation Steps:

- Connect the generator output to a compression chiller.
- Use the chiller for air conditioning or industrial cooling.

- Optimize load sharing to balance power supply and cooling demand.

Example Applications:

- Commercial Buildings → Cooling during peak power outages.
- Industrial Plants → Cooling machinery while running backup power.

System Components & Technical Specifications

The **OptiPrime range** offers gensets from **2500 kVA to 6600 kVA**, providing robust and scalable power solutions. Each genset emits **waste heat**, which is utilized in the trigeneration process to enhance overall efficiency.

Model	**Power Output (kVA)**	**Fuel Input (MW)**	**Electric Efficiency**
OptiPrime 2500	2500 kVA	6 MW	40-42%
OptiPrime 3000	3000 kVA	7.5 MW	41-43%
OptiPrime 5000	5000 kVA	12 MW	42-45%
OptiPrime 6600	6600 kVA	14.5 MW	43-46%

Kirloskar Powergen offers **three types of absorption chillers**, optimized for different applications. Kirloskar provides specialized **absorption chillers** to maximize cooling efficiency, depending on the application.

- **Composite Chillers (25 - 200 TR):** Best suited for food processing and cold storage.
- **Zero Degree Vapour Absorption Chillers (50 - 1000 TR):** Ideal for data centers and pharmaceutical facilities.
- **Chiller + Hot Water Generator (50 - 2000 TR):** Designed for commercial buildings, hotels, and large industrial complexes, providing both cooling and hot water.

These chillers use an **advanced lithium bromide-water cycle**, offering chilled water outputs ranging from **7-12°C**, ideal for HVAC and industrial applications. The total system efficiency is calculated as follows. By applying this formula, the OptiPrime series consistently achieves efficiencies between **65% and 85%**, significantly outperforming traditional diesel generators. For example, the **OptiPrime 6600** kVA Quad Core Power

System with a **fuel input of 14.5 MW**, produces **6.6 MW of electricity**, **5.5 MW of recoverable waste heat**, and **4.13 MW of cooling output**, resulting in a remarkable **overall efficiency of 65% to 85.3%**.

Chiller Type	**Cooling Capacity (TR)**	**Heat Source**	**Best Application**
Composite Chiller	25 - 200 TR	Steam / Hot Water	Cold Storage, Food Processing
Zero Degree Vapour Absorption Chiller	50 - 1000 TR	Exhaust / Hot Water	Data Centers, Pharma
Chiller + Hot Water Generator	50 - 2000 TR	Exhaust / Steam	Hotels, Commercial Buildings

These chillers use a **lithium bromide-water cycle** to convert waste heat into **chilled water (7-12°C)** for cooling applications. The **overall efficiency** is calculated as:

$$\eta_{trigeneration} = \frac{P_{electric} + Q_{useful\ heat} + C_{cooling}}{Q_{fuel\ input}} \times 100$$

OptiPrime Model	**Fuel Input (MW)**	**Electric Output (MW)**	**Waste Heat Recovery (MW)**	**Cooling Output (MW eq.)**	**Overall Efficiency (%)**
OptiPrime 2500	6 MW	2.5 MW	2.0 MW	1.76 MW	Upto 85%
OptiPrime 3000	7.5 MW	3.0 MW	2.5 MW	2.07 MW	Upto 85%
OptiPrime 5000	12 MW	5.0 MW	4.5 MW	3.52 MW	Upto 85%
OptiPrime 6600	14.5 MW	6.6 MW	5.5 MW	4.13 MW	Upto 85%

Economic Benefits

- 30-40% reduction in fuel costs
- Fast ROI (1.5 - 4 years)
- Lower electricity costs for cooling (up to 50% savings)

Environmental & Sustainability Benefits

- 30-50% reduction in CO2 emissions
- ESG & Green Building Compliance
- Supports Net Zero energy goals

Operational & Reliability Benefits

- Continuous power & cooling for critical operations
- Lower maintenance costs due to heat recovery
- Scalable & modular system suitable for diverse industries

OptiPrime Trigeneration series for the Green Data Center

The value proposition from the OptiPrime Trigeneration series is unique and changes as per the target segment. For example, Data centers require stable cooling for servers.

Segment	**Pain Point**	**OptiPrime Trigeneration Value Proposition**	**Sales Approach**	**Value Proposition**
Data Centers	High cooling & power costs	**30-50% savings on cooling energy**	Partner with major data center operators	Provides **stable HVAC cooling** for servers
Pharma & Chemicals	Need process cooling & heating	**20-30% operational cost savings**	Direct B2B sales to pharma plants	**Process cooling & precise temperature control**
Hotels & Real Estate	HVAC & hot water energy bills	**Up to 40% reduction in electricity costs**	Work with facility management firms	Offers **simultaneous HVAC cooling + hot water**

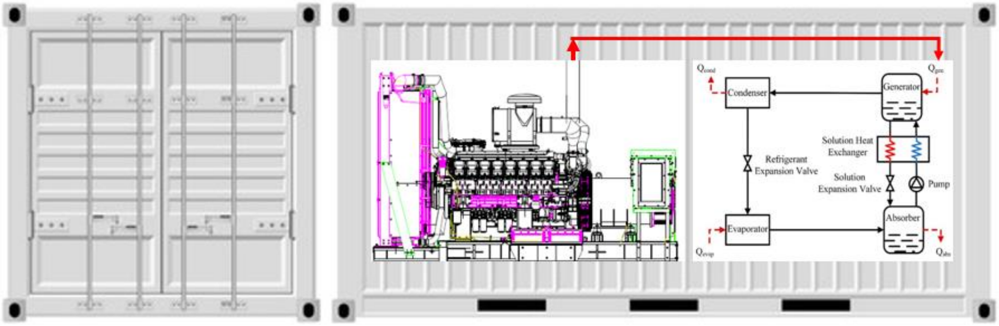
Most OptiPrime Trigeneration Series units deployed in data centers will operate as standby power solutions, meaning they are not continuously running, but instead activate during power outages or peak load conditions. Despite this, they still provide stable and efficient HVAC cooling when needed.

When a power outage occurs, OptiPrime standby gensets automatically start, ensuring an uninterrupted power supply to critical server loads. Simultaneously, the waste heat recovery system is activated to supply thermal energy to the Kirloskar Absorption Chillers, providing cooling without relying on grid electricity.

How It Works in Standby Mode:

1. Grid Power Failure Detected: The standby OptiPrime genset starts immediately.
2. Power Supply Restored: The genset supplies electricity to critical IT loads.
3. Waste Heat Recovery Activates: The exhaust gas and cooling system heat are diverted to the absorption chiller.
4. Cooling Restored: The chilled water system is reactivated, ensuring that server rooms maintain safe operating temperatures.

This entire process occurs within seconds, ensuring that no thermal buildup occurs in the data center.



Particulars	Size	Size
Diesel Generator	1 MW	1 MW
Fuel Energy	2.38 MW	2.38 MW
Electricity at 100%	1250 kVA	1250 kVA
Balance	1.38 MW	1.38 MW
1 MW to HVAC through HR	300 TR	150 TR
System Effeciency	84%	63%

Figure 5: The OptiPrime Trigeneration Series with inbuilt heat recovery through vapour absorption chiller cycle

Ensuring Consistent Cooling in a Standby Setup

Since standby generators do not run continuously, the system must ensure cooling stability before, during, and after an outage. The OptiPrime system achieves this through multiple backup mechanisms:

- **Thermal Energy Storage (Cold Water Tanks):**
    - Chilled water storage tanks maintain a reserve of cool water that can continue cooling during the generator startup phase.
    - This acts as a buffer, preventing sudden temperature spikes in CRAC (Computer Room Air Conditioning) units.
- **Fast Startup & Load Synchronization:**
    - OptiPrime gensets are designed for quick startup times, ensuring that both power and cooling systems resume operation without delay.
    - Automatic Load Transfer Systems (ATS) ensure seamless switching from grid power to generator power.
- **Hybrid Cooling Integration:**
    - If grid power is partially available, the absorption chiller can use alternative heating sources (steam/hot water from other backup systems) to maintain cooling until the genset is fully operational.

Energy & Cost Savings Even in Standby Operation

Even though the OptiPrime Trigeneration system is a standby unit, it still provides significant cost benefits:

- **Grid-Independent Cooling During Outages:**
    - Traditional data centers rely on electrical chillers powered by UPS batteries, which can drain reserves quickly.
    - OptiPrime utilizes free waste heat to generate cooling, extending UPS runtime for critical systems.
- **Fuel Savings in Standby Mode:**
    - Since the gensets run only when needed, overall fuel consumption is lower than continuously running prime units.
    - Absorption cooling eliminates the need for separate electric chillers, further reducing diesel consumption during generator operation.

Even in a standby setup**, OptiPrime** scales match the data center's cooling requirements**:**

Data Center Load	**OptiPrime Model**	**Chiller Type**	**Cooling Capacity (TR)**
1-5 MW Load	OptiPrime 2500	Zero Degree Absorption Chiller	400-600 TR
5-10 MW Load	OptiPrime 5000	Zero Degree Absorption Chiller	800-1000 TR
10+ MW Load	OptiPrime 6600	Chiller + Hot Water Generator	1000-2000 TR

The system automatically adjusts cooling output based on load conditions, ensuring that only the necessary capacity is activated, further optimizing fuel usage.

Final Standby Cooling Design Summary

Category	**Traditional Genset + Electric Chiller**	**OptiPrime Trigeneration Standby System**
Cooling Power Source	Grid electricity or UPS	Waste heat (no electricity needed)
Startup Time	~30 sec - 2 min	Immediate with thermal storage backup
Cooling Redundancy	None, relies on grid UPS	Chilled water storage + hybrid heat input
Energy Cost Savings	₹0 Cr saved annually	₹7.2 Cr saved annually
CO_2 Emissions Reduction	Higher emissions	30-50% lower emissions

ESG Compliance & Sustainability Even in Standby Mode

Even though standby gensets are not continuously running, OptiPrime Trigeneration contributes to data center sustainability goals:

- Reduces Grid Dependence: Uses waste heat for cooling, lowering reliance on electric chillers.
- Lower Carbon Footprint: Cuts CO_2 emissions by 30-50% when operational.

- Meets Green Certification Standards: Aligns with LEED, ASHRAE, and ESG compliance requirements.

Final Takeaway: Even as a standby power source, OptiPrime Trigeneration ensures continuous HVAC cooling for data centers during power outages while optimizing energy efficiency and reducing operational costs.

Payback within 1.5 to 4 years with OptiPrime Trigeneration Series

The payback is within 1.5 years assuming continuous/prime operation and ~4 years in case of standby operation. For standby application it would depend on the extent of usage. Even in case of standby the calculation can be based on customer site requirement. Irrespective, the savings are significant for the end customer because the HVAC load will come down to the extent of cooling from OptiPrime Trigeneration series. You can get efficiency of between 65% to 85% from the OptiPrime Trigeneration series VS that of ~40-45% in a conventional diesel generator. The cooling power shall be via absorption chiller through flu gas/waste hear recovery system. This results in a significant reduction in Total cost of ownership and carbon emissions.

Feature	**OptiPrime Trigeneration**	**Conventional Diesel Genset + Grid Cooling**
Fuel Efficiency	65- 85% (Trigeneration Mode)	40% (Genset Alone)
Cooling Power Source	Free Cooling from Waste Heat	Expensive Grid Power
Carbon Emissions	30-50% lower CO_2 footprint	Higher carbon emissions
Flexibility	Scalable, works with renewables	Standalone only
Return on Investment (ROI)	1.4 – 4.0 years	5+ years (higher OPEX)

Summary: Moving towards the Green Data Center with OptiPrime Power Systems

The OptiPrime multi core power systems and the OptiPrime Trigeneration Series are a transformative solution in the distributed energy sector, offering unparalleled efficiency, sustainability, and cost-effectiveness. As industries shift toward net-zero energy targets, OptiPrime power systems will play a critical role in net zero systems while maintaining operational resilience.

By adopting OptiPrime Multi Core Power Systems, Data Centers gain a high-performance energy system that enhances efficiency, lowers costs, and promotes environmental responsibility, solidifying Kirloskar's leadership in the next generation of sustainable power solutions.

Authors

Dr. Krishna Lakshminarasimhan- Chief Technology Officer & VP Engineering
Dr. Yogesh Aghav- Head of Advanced Engineering
Devang Kansara- Head of Power Generation Engineering
Gaurav Bhalla- Head of Power Generation Projects
Abhijeet Vaze- Head of Combustion & Platform Engineering