SCALABLE POWER TO MATCH INDUSTRIAL PARK GROWTH IN SOUTHEAST ASIA

POWERPHASE® GENERATION SMART

COUNTRY
MALAYSIA

PROJECT SUMMARY

Powerphase recently installed two Turbophase modules at a Malaysian high-tech park, one of several projects it has underway in Asia. Ensuring reliable and efficient natural gas capacity is a challenge in the fast-growing Southeast Asian grid. Southeast Asia's hot climate is a challenge for efficient CCGT operation because hotter ambient temperatures reduce air density and GT combustion efficiency. Turbophase technology is modular, compact, and can be integrated into an existing plant's footprint so Southeast Asian plant operators don't have to undertake new land, transmission, or fuel supply pipeline surveying, permitting, design, and construction.

Powerphase takes a consistent engineering approach for all its projects. The Turbophase system implementation plan began with a feasibility study, followed by a turnkey pilot project and full implementation designed to support future growth. Powerphase engineers estimate that the power plant could increase its generating output by 10 percent, with 8 Turbophase modules, while building out far less than tenth of the plant's current footprint.

As the number of tenants in the industrial park continues to grow so will electricity demand and the client will meet that demand with additional Turbophase modules. Until then, the additional 8.5 MW of electricity generated by the Turbophase system will provide the generator will additional profits now since they won't have to purchase as much power from the grid.

To ensure true turnkey capabilities, Powerphase designed a custom integration for the CCGT plant to accommodate plant configuration, future electricity demand, and local environmental regulations. The plant needed the Turbophase system air pipe to traverse 220 meters to connect the Turbophase system to the gas turbines.

BY THE NUMBERS

Engine Type	GE 6B
Configuration	Combined Cycle
Megawatts As Installed	4.25 MW Per CT
Megawatts Potential	4.25 MW Per CT
Reduced Use of Grid Power	Yes
Industrial Park Profitability Growth	Yes

Powerphase designed the air pipe to support future growth, using a 12-inch diameter pipe that can support up to 8 Turbophase modules. The gas supply line follows the same path as the air pipe, connecting the GT and Turbophase system. The gas line is a 4-inch diameter pipeline that fuels the Turbophase modules at a low pressure, 5 psi. The exhaust system was also custom designed to meet local environmental protection requirements of being at least 1 meter above structure with no bends. Typically, Powerphase would install an exhaust pipe with a 90-degree bend, but had to change alignment and add ports to top of stack to meet environmental requirements.

MARKET BACKGROUND

Asia's power generators are seeking more capacity at greater efficiency with lower emissions. By 2040, the Asia Pacific region will see as much investment in power capacity as the rest of the world combined, coming in at an estimated $4.8 trillion according to Bloomberg New Energy Finance. Of this investment, 10 percent is predicted to be spent on gas- and coal-fired power. Although coal is expected to account for 34 percent of the region's power generation in 2040, peak coal capacity is predicted to occur in 2024 and peak coal-fired generation in 2028, as power plant retirements begin to overtake additions and air pollution concerns continue to rise.

Asian power producers may be able to make the most of their existing natural gas infrastructure with a performance boosting technology. Earlier this year Powerphase signed an MOU to install two Turbophase modules on an Indonesian CCGT plant, with expectations that it would become 50 to 55 percent more efficient than existing Indonesian simple cycle natural gas-powered plants with upgrade costs 66 percent less than that of a new combined-cycle plant. It will directly

offset peaking plants, which are only 35 percent efficient. Most critically, the Turbophase system can be deployed rapidly. Powerphase estimates that the 2 GW enhancement can be demonstrated within two years. These efficiency gains will improve Indonesia's grid efficiencies quickly and economically.

CUSTOMER CHALLENGES

While Asian countries are adding significant amounts of renewable power to replace coal, with a 2-3 percent annual increase in investment, a significant amount of gas-fired power is still needed. The International Energy Agency (IEA) has said gas will be increasingly adopted over coal by 2025, due largely to Asian countries' air pollution concerns. With fast growing electricity demands, Asian nations need clean energy resources that can be quickly deployed. One possible solution is to boost their existing natural gas generating capacity, which can help them get the most out of existing infrastructure while developing more renewable and gas-powered generation.

Ensuring reliable and efficient natural gas capacity is a challenge in the fast-growing Southeast Asian grid. All over the world, electricity market operators dispatch gas turbines in order of efficiency. The last turbine can be up to 30 percent less efficient than the first one that came online. Installing Turbophase on the grid allows the grid operator to shut off the least efficient turbines. Turbophase systems can be installed very quickly and deliver significant amounts of incremental power. They can be deployed around the entire power grid at existing plants, eliminating the challenges associated with new build such as land acquisition, transmission connections, and fuel sourcing.

PROJECT MILESTONES

Powerphase has installed two air-cooled Turbophase modules on two CCGT plants, at a Malaysian high-tech park, to provide up to 50 MW of additional capacity. The project began at the beginning of 2017, with permits obtained in May, and construction completed over Summer 2017. In January 2017, Powerphase signed an agreement with the customer and then spent about 4 months preparing drawings and preparing project supplies.

After breaking ground in late May, Powerphase prepped the installation area by reinforcing wet ground in the area with 12- to 18-meter pilings to support concrete platforms for the Turbophase system. The Turbophase modules and roof skids for the auxiliary air cooling systems arrived the first week of July. The roof skids are modular and took only one shift to install on top of the Turbophase modules, which is a plug-and-play process of assembling the box support on the ground, lifting it with cables and aligning it with the Turbophase module, bolting it into place, and then lifting the skid and pinning that onto the box support. With all the modular pieces arranged and staged, the Powerphase team completed the Turbophase system assembly in four days and had it fully commissioned and running within two weeks.

In parallel with Turbophase module assembly, the Powerphase team was developing integration infrastructure between the Turbophase system and the plant. The team installed the head-end pipeline, a pipeline system to collect Turbophase module output and feed it to the gas turbines, and an electronics control center to control each Turbophase module and interface with the GT.

The Powerphase team designed a custom air pipe and fuel supply line. The plant needed the air pipe to traverse 220 meters to connect the Turbophase system to the gas turbines. The air pipe took 3 to 4 weeks to complete, and upon completion just needed to connect to the Turbophase module output nozzles. supply and Turbophase system. The gas line is a 4-inch diameter pipeline that fuels the Turbophase modules at a low pressure, 5 psi.

NEXT STEPS

The Malaysian natural gas power plant is fortunate to have a large footprint. It has room for growth, with enough space for 4 new GTs in future, and corresponding air-cooled condensers. Powerphase engineers estimate that the power plant could increase its generating output by 10 percent, with 8 Turbophase modules, while building out far less than tenth of the plant's current footprint. The high-tech park uses all of the plant's power, and anticipates significant growth. Having a reliable source of electricity is important to the high-tech park's tenants. Today, the high-tech park is the Malaysian outpost of several western high-tech companies that include Intel and First Solar. It contracted Powerphase with the plan to support an incoming tenant that would build a new manufacturing plant, that wouldn't have to rely on the public power grid resulting in a lower cost of power to the high-tech park customers and more profits for the generator.

In Summer 2018, when two more tenants move into the high-tech park, the Turbophase system will be operating 24 hours, 7 days a week to boost power generation. The high-tech park anticipates that with the new tenants, it will be using all of the GT electricity output and need to expand again.

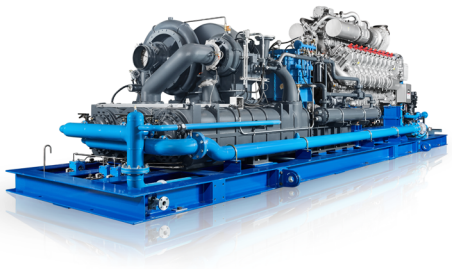
HOW IT WORKS

The Challenge for Gas Turbine

Gas Turbines draw ambient air into their axial flow compressor, increasing the temperature and pressure of the air. The air then flows into the combustor where fuel is added proportionate to the amount of air mass flow and the mixture is ignited. This high-energy gas now expands through the turbine stages, creating mechanical torque to drive the gas turbine's compressor and the net torque drives the generator producing electrical power.

The challenge faced by all gas turbines is that as ambient temperature or elevation rises, the density of the air naturally decreases, reducing the mass flow into the gas turbine. This reduced mass flow results in reducing the fuel flow proportionately to hold turbine inlet temperatures constant. This results in lower output.

Turbophase restores the mass flow that is naturally missing by injecting air into the compressor discharge. The gas turbine control system reacts naturally and adds a proportionate amount of fuel to account for the increase air mass flow, resulting in constant combustion and turbine inlet temperatures. The increased mass flow through the turbine section increases the mechanical torque to the compressor and generator.



How Turbophase Meets the Challenge

Turbophase is a packaged system with a reciprocating engine driving a multi-stage, intercooled centrifugal air compressor. Air is drawn into system to ventilate the system and provide air to the compressor. The compressor air filtration system mirrors the air quality of the gas turbine and then is compressed by the first stage of the air compressor and then cooled. The inter-cooled process is repeated through four or five stages, depending on the desired pressure, resulting in less power required per pound of air compressed compared to the axial compressor in a gas turbine.

How Turbophase Modules are Installed at a Power Plant

A Turbophase system can have several modules and each module produces a certain mass flow of pressurized hot air. Each module is factory acceptance tested to ensure quality including correct air pressure and temperature prior to shipment to the power plant site. Depending on the size of the gas turbine, and the requirements of the power plant, a Turbophase system may have 1 module or more than 10 modules. Each module is approximately 32 feet long by 8 feet wide by 18 feet tall at its highest point. A typical Turbophase installation requires no unplanned outage at the plant.