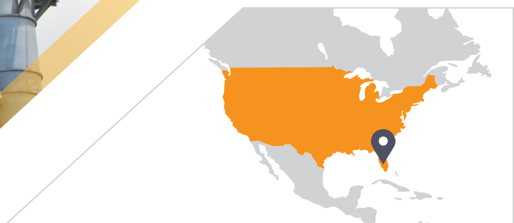
FLORIDA GRID EFFICIENCY: EQUAL TO REMOVING 1 MILLION CARS FROM THE ROAD

POWERPHASE® GENERATION SMART

COUNTRY
FLORIDA
U.S



PROJECT SUMMARY

Powerphase commissioned a grid level analysis to assess how Turbophase technology could increase existing natural gas combined cycle gas turbine (GT) efficiencies in Florida, displacing baseload coal-fired generation and inefficient peaking plants to reduce electricity costs and pollution. Today's electricity prices in Florida are higher than the national average, and while most of this electricity is generated from low-carbon natural gas, the state's Public Service Commission (PSC) believes that natural gas-based generation should be increased to reduce electricity prices and environmental impacts.

The Powerphase study used the PLEXOS model, an Integrated Energy Model that accounts for production cost, mid-term optimization, capacity expansion and planning, and reliability evaluation. It uses the EPA's Continuous Emissions Monitoring (CEMS) database to estimate pollutant emissions. The PLEXOS model simulates the complexities of energy markets and can bring insights into risks and rewards when there are many moving parts. The integrated database optimizes baseload supply, ancillary services, renewables, and generation and transmission. As a result, users gain understanding of how deploying new assets, revising public policy, or changing regional market rules can affect electricity supply, plant dispatch by fuel type, and pollutant emissions.

To fully capture likely natural gas capacity dispatch, the PLEXOS model included the Southern Company balancing authority from the Southeast Reliability Council (SERC) region and Florida Reliability Coordinating Council (FRCC) zones. The PLEXOS model simulated 2015 hourly dispatch of plants within FRCC and between FRCC and SERC to understand how Turbophase could boost existing natural gas generation in Florida. Installing Turbophase on all of Florida's natural gas combined cycle GT (24.6 GW) would boost their generation output by 15 percent, or 3.7 GW. This additional generation capacity would reduce peaking plant dispatch by 65 percent, and coal-based power production by 25 percent. Accounting for natural gas capacity boost and displacing coal-fired capacity, the study showed that FRCC can avoid $96 million in energy costs for Florida ratepayers if Turbophase is widely deployed. It would also reduce CO2 emissions by 4.8 million tons, equal to 1 million cars being taken off Florida's roadways.

The PLEXOS study shows that Turbophase could help the Florida PSC achieve its goals of increasing natural gas electricity generation to stabilize ratepayer costs and reduce environmental impacts from current FRCC's current capacity mix. A roadmap to plan its widespread deployment could be devised by a working group comprised of Florida utilities' plant operators and load planners, PSC regulators, and FRCC market operators. Such a working group could assess the feasibility of deploying Turbophase on all of Florida's natural gas combined cycle GT plants. A roadmap to boost existing combined cycle GT plant performance would account for planned capacity investments already in queue, to determine whether they need to be re-prioritized to quickly deploy Turbophase on existing natural gas combined cycle plants. It could consider tradeoffs between investing in plant upgrades with Turbophase v. new natural gas GT capacity, prioritize existing plants to schedule Turbophase deployment, examine economies of scale to upgrade Florida's existing GT capacity, and define a benefit-cost analysis framework to ensure the most value to Florida's ratepayers.

BY THE NUMBERS

	FRCC Regions w/o TurboPHASE	FRCC Regions w/o TurboPHASE	DELTA
Production Cost Savings	$4,421,651,989	$4,325,586,191	$96,065,798
Annual Gas Burn	674433	704622	30,189
Annual Emissions			
CO2 (ton)	70,244,890	65,459,235	4,785,655
SO2 (ton)	52,387	38,148	14,239
Nox (ton)	40,334	32,510	7,824

MARKET BACKGROUND

Florida switches back and forth with Texas for winning the title of being the state with the highest proportion of natural gas electricity generation. More than three-fifths of Florida's power comes from natural gas. Although most of Florida's electricity is generated by natural gas, almost 23 percent of its electricity supply comes from coal. And according to the Institute for Energy Research, Florida "has moderately expensive electricity, higher than the national average" and "generates more electricity from petroleum, in absolute terms, than any other state." In 2015, Florida's coal plants operated 80,097 hours, producing 26.7 million tons of CO2. Regarding Florida's energy future, Florida PSC chairman, Ronald Brisé said, "increased use of natural gas in Florida reduces overall energy costs and lessens environmental impacts."

New gas capacity is being built to meet the Commissioners goals of reducing energy costs and environmental impacts. Gas plants can be built with increasing efficiency: simple cycle, combined cycle, or aeroderivative GT technology. However, these systems take time to permit, build, and commission. Turbophase modules can help fill the gap today and beyond. The Turbophase system can boost capacity at existing GT plants, growing existing capacity quickly because they take only a few months to install and commission.

CUSTOMER CHALLENGES

Maintaining consistent power output can be challenging for a combined cycle gas turbine (CCGT) in Florida, given its hot climate and even hotter summers. Heat leads to turbine inefficiencies because hotter ambient temperatures reduce air density and GT combustion efficiency.

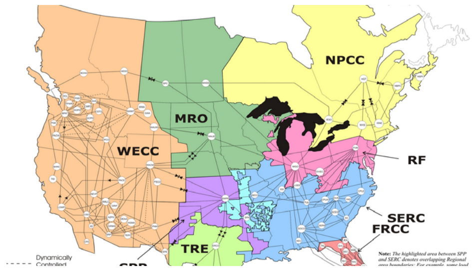
On any given day, baseload electricity demand is met by coal-fired plants and CCGT plants. However, on a hot day when CCGT plants are not able to optimally operate, baseload and additional peak demand must be filled in by other plants. Coal-fired capacity continues to operate as it normally would, unaffected by the weather. Power plants dispatched to meet peak demand are often the most expensive to run due to outdated technologies that make them inefficient, or expensive fuel such as petroleum.

There are two options to meeting the Florida PSC goals of increasing natural gas use. One, more natural gas plants could be built to displace existing coal-fired baseload and inefficient peaking plants. Two, existing natural gas GT efficiencies could be boosted. In fact, boosting GT power production could provide a near-term solution while new natural gas capacity is deployed and a long-term solution to enhance legacy and newer GT powered plants.

One way to increase GT power production is to install chillers to cycle cold water from a cold tank to a hot tank through the turbine's inlet to boost power production. However, the chillers draw power from the turbine to refrigerate the water for 16 to 18 hours a day. Therefore, the chiller can only run 6 hours a day while parasitically reducing electricity output from the turbine. A Turbophase system is a superior substitute to a chiller, as it can be available 24 hours a day to boost air flow to the CCGT.

PROJECT MILESTONES

In 2015 Powerphase commissioned a PLEXOS study, covering the FRCC, to assess the benefits of deploying Turbophase modules on combined cycle GT units in the State of Florida. The PLEXOS FRCC dataset accounts for 40.3 GW of natural gas generation, of which 24.6 GW are combined cycle plants, and 9.9 GW of gas peaking power. Peaking plants can provide a 10-minute spinning reserve and contribute towards a 2.5 percent load risk in the FRCC region. The study assumes that Turbophase modules can be placed on all the combined cycle GTs, producing an incremental 15 percent power boost of 3.7 GW for the FRCC territory. Gas fuel prices were assumed to follow historical Florida citygate fuel pricing. To fully capture likely natural gas capacity dispatch, the PLEXOS model included the Southern Company balancing authority from the SERC region. All FRCC zones (FMPP, FPC, FPL, GVL, JEA, SEC, TAL, and TEC) were included.



The PLEXOS model simulated 2015 hourly dispatch of plants within FRCC and between FRCC and SERC to understand how Turbophase could boost existing natural gas generation in Florida.

The PLEXOS model showed that Turbophase boosted natural gas capacity by 15 percent, so that 2015 generation would have increased from 137,738 GWh to 146,545 GWh. With this increase in natural gas capacity, less peaking capacity and coal baseload were needed. Simulations showed that with Turbophase deployed on all existing combined cycle GTs, 2015 peaking plant operations would have decreased from 131 hours to 39 hours and 2015 coal-fired operations would have decreased by 25 percent, from 80,097 hours to 60,411.

Therefore, accounting for natural gas capacity boost and displacing coal-fired capacity, the study shows that FRCC can avoid $96 million in energy costs per year for Florida ratepayers if Turbophase is widely deployed.

NEXT STEPS

The PLEXOS study shows that Turbophase is a potential solution to Florida PSC goals of increasing natural gas electricity generation to stabilize ratepayer costs and reduce environmental impacts from current FRCC's current capacity mix. It could be an economical solution to boosting low-carbon electricity generation in Florida. However, deploying any technology, including a modular one that can be deployed within a few months' time like Turbophase, requires strategic budgeting and planning.

The FRCC, PSC, and generating utilities will need to convene a working group that can assess the feasibility of installing Turbophase on the state's combined cycle GT plants. The working group would provide a roadmap to enhance the efficiency of existing GT infrastructure.

It would also draw upon expertise from the FRCC wholesale market oversight, PSC goals to provide ratepayer value, and generating utilities' plant engineering and load research departments. Goals could include prioritizing existing plants to schedule Turbophase deployment, economies of scale to upgrade Florida's existing GT capacity, and a benefit-cost analysis framework to ensure the most value to Florida's ratepayers. The final roadmap would outline a timeframe for combined cycle GT upgrades, specifying plants to be upgraded on an annual basis, with a clear definition of how the proposed solution will save ratepayers the most money in the long run.

A roadmap to boost existing combined cycle GT plant performance would account for planned capacity investments already in queue, to determine whether they need to be re-prioritized to quickly deploy Turbophase on existing natural gas combined cycle plants.

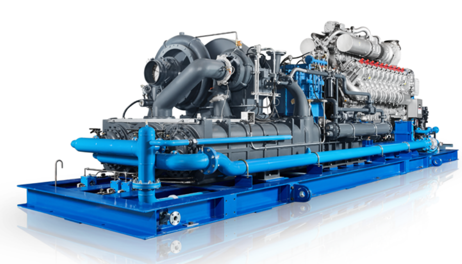
HOW IT WORKS

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.