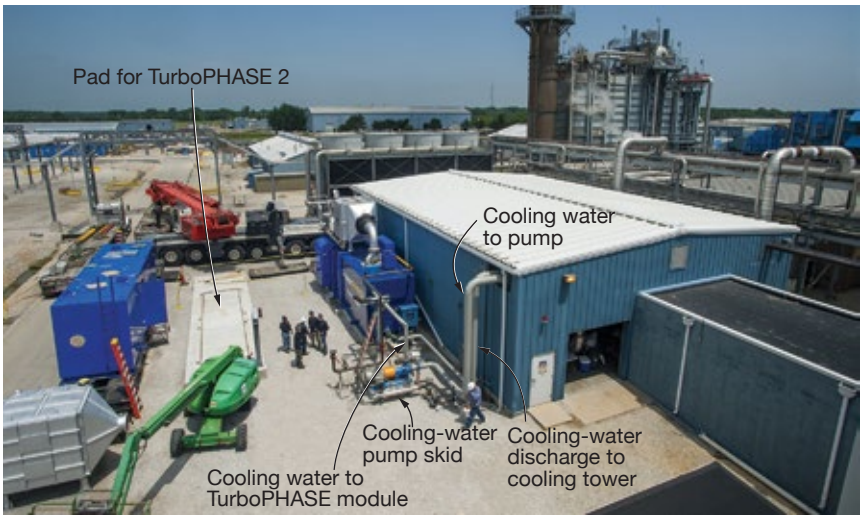
Well-timed megawatts offer potential value to Morris Cogen

Soon, you may be adding a new option for extracting megawatts from your gas turbine/generator or combined cycle—a separate engine-driven compressor module that takes high-temperature turbine exhaust and feeds it back into the GT's compressor discharge. Called TurboPhase, it's a deceptively simple technique. If the initial installation at Morris Cogeneration LLC lives up to its promise (Fig 1), it could challenge traditional capacity enhancement options, like inlet air chillers, foggers, water or steam injection, and duct-burner firing.

Such options are receiving greater attention these days because grid operators are rewarding generators for the flexibility and quick-response capabilities necessary to meet their ancillary-services obligations. However, the cost/benefit analysis can be complicated.

Morris Cogen, owned by Atlantic Power Corp, is a 177-MW combined-cycle facility with three GE Frame 6B gas turbine/generators and HRSGs, and a 60-MW steam turbine/generator, supplying a large ethylene manufacturing plant in Morris, Ill (near Chicago) with over 1-million lb/hr of steam and electricity since 1997. Excess power—about 120 MW—is sold into PJM. This year Morris pioneered the installation of two TurboPhase modules, now being commissioned and tested.

According to Joe Nichols, facility O&M manager, there are multiple



1. Engine-driven compressor modules help Morris Cogen provide ancillary services through the PJM regulation market

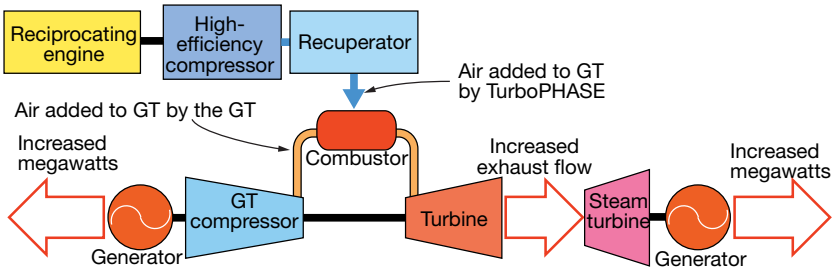
How TurboPhase works

PowerPhase LLC engineers say their company's TurboPhase product can boost the output of a combined-cycle plant by up to 15%, and a simple-cycle gas turbine by up to 20%. The skid-mounted turbocharger generally relies on an efficient reciprocating natural-gas or diesel engine and an intercooled compressor to inject hot high-pressure air directly into the combustion section of the GT, thereby increasing mass flow through the turbine (Figure).

The additional power is available within a minute or so of starting the auxiliary engine. For a 7FA.04-equipped 2 × 1 combined cycle, a 5% TurboPhase injection into each gas turbine means more than 40 MW is available (18 MW from each GT, plus 5 MW from the steamer) almost instantly.

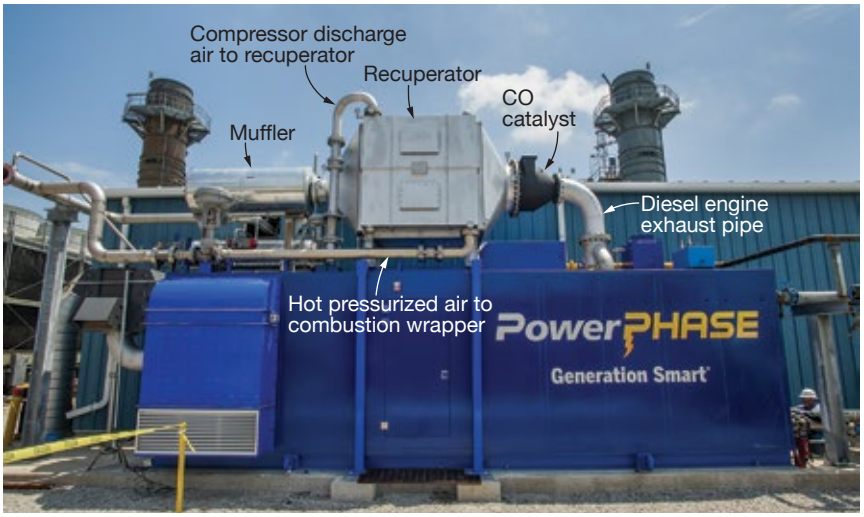
The amount of air injected into a given gas turbine is determined by an engineering study that considers specific limits of plant equipment—such as the GT, generator, transformer—as well as the ambient range for which the extra power is desired. Typically, the equivalent of from 5% to 10% of compressor inlet air can be added in the combustion section.

PowerPhase engineers say it is a less costly and more efficient alternative than steam injection and air inlet chillers for increasing combined-cycle output and performance on hot days. Steam injection and inlet chilling can match the GT power boost of TurboPhase, but those alternatives reduce steamer output and increase parasitic power consumption, penalizing both total output and heat rate. Fogging is an efficient way to increase power, but the amount of additional output is limited. Likewise, duct burners can add peak power, but there's an efficiency penalty.

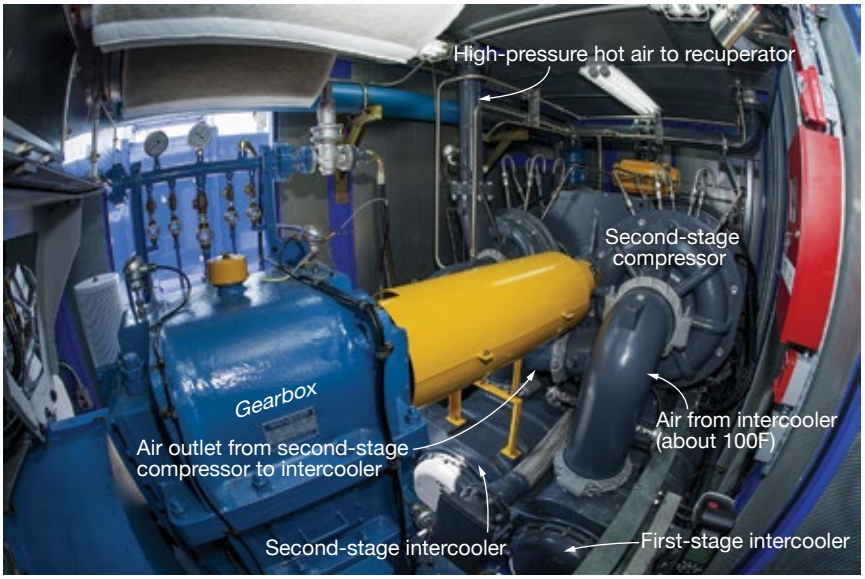


TurboPhase is a turbocharger that can benefit both simple- and combined-cycle plants. It actually improves the efficiency of simple-cycle engines

2. Cooling water for the modules is tapped from the nearby cooling tower lines, delivered via adjustable speed pump



3. Many GTs, including this frame 6B, have a flanged port for supplementing air flow lost in hot weather



4. Intercoolers boost compressor efficiency

benefits, but the greatest is probably the dollars that can be generated each month by responding more quickly (under a minute) with additional incremental megawatts (up to 7 MW) to satisfy PJM's new requirements in the performance-based frequency regulation market.

Nichols explained that all resources wishing to supply regulation have to pass PJM's multiple tests and are scored. Improving this "score" increases the amount of money a facility can make. TurboPhase helps Morris up its score by five to 10 percentage points and improves their bids into the day-ahead market.

The gain comes because the gas turbine can respond much faster than the steam turbine and because the technique has almost zero parasitic penalty to the GT facility output (although it does involve its own source of fuel and the engine is a new point source that has to be permitted). Other benefits include reducing the operation of the chillers for inlet-air cooling, reducing the load on the steam turbine, and avoiding incremental duct firing.

Nichols said the facility also is looking at a storage module to continue to capitalize on these new market opportunities. Because of interconnection issues, there is also a benefit to adding or subtracting incremental megawatts without having to open or close a breaker, or adding a new breaker, such as with a new unit.

The only things Nichols groused about was that the project team substantially under-estimated the budget for piping and that the official commercial operating date was behind schedule by a few weeks.

To understand where the value comes in, consider that PJM is a sprawling interconnected grid that hop-scotches from north central Illinois to Pennsylvania and New Jersey. PJM originally stood for Pennsylvania-New Jersey-Maryland Interconnection, a cooperating region for wholesale power sales and grid management before deregulation, and was where the heart of the grid had been.

PJM's territory today is a result of various utility expansions and memberships, most notably the merger of the old Philadelphia Electric Co with Commonwealth Edison Co of Chicago (and northern Illinois) to form Exelon. Morris Cogen sits at the western edge of PJM. The extremities of any electricity grid, whether you are on the end of a distribution feeder or the edge of the grid, tend to exhibit stability problems. Under the old electricity system, utilities provided ancillary services to maintain an overall stable grid.

Today, ancillary services are procured from the market. In theory, anyway, this should reduce the level of reserves required in the system. Morris, like many resources, essentially is now going to be paid by PJM to help maintain stable frequency levels in that part of the grid.

Scott Auerbach, director of engineering for PowerPhase LLC, will be the first to tell you how straightforward the TurboPhase concept is. The TurboPhase modules (TPM), packaged in Korea, require only the following to implement:

- One flanged connection, on the compressor discharge plenum.
- A cooling-water take off (in Morris' case, supply is from the nearby cooling tower, as shown in Fig 2).
- A small fuel line (Morris has a 2 in. pipe).
- Integration of the module's controls into the cogen facility's existing systems.

Importantly, Auerbach notes, no warranty issues arise with the turbine OEM because the machines are designed with such additional air flow in mind. "Some of these units even come with a flanged port for such purposes," he said. In essence, Auerbach continues, TurboPhase adds back in the air mass flow lost when GTs run at high ambient temperature (Fig 3). Design air flow out of TurboPhase is 650F and up to 300 psig.

The system is designed to fail-safe in all cases and protect the GT. To ensure that the TurboPhase air flow does not "shock" the GT, operating guidelines call for equalizing the pressure upstream of the control valve just ahead of the GT compressor injection point before opening the valve and allowing flow to occur. The other trick is to get distribution to all of the GT combustion chambers so that combustion dynamics are not disturbed. Equalizing the pressure helps in this regard as well.

A few other aspects of the system will be of interest to simple- and combined-cycle owner/operators. For example, the engine is paired with a four-stage intercooled centrifugal compressor (Fig 4). This boosts efficiency but does add components. Another component not often found at powerplants is the shell-and-tube recuperator, which recovers heat from the engine exhaust and transfers it to the discharge of the TurboPhase compressor before it is added to the discharge of the GT compressor. A variable-speed pump is used to move cooling water through the TurboPhase package.

TurboPhase employs an MTU gas-fueled reciprocating engine rated at 2000 kW and 43% efficiency. The exhaust ducting includes a small CO catalyst unit.

Speed control has been one challenge in the early commissioning work, notes Auerbach, in part because this is a gas-fueled engine and because it is designed, and must be tuned, for very low emissions. Fuel/air ratios are constantly adjusted based on readings from NO_x sensors in the exhaust.

The reciprocating engine "communicates" with the TPM compressor through speed control. Opening and closing the TPM's inlet guide vanes changes the reciprocating engine output, and the engine has to accommodate these load changes by increasing or decreasing speed while avoiding compressor critical speeds close to 3600 rpm. This is a little tricky, says Auerbach: A gas-fueled recip, compared to liquid fuel, exhibits a slight time lag because the natural gas has to be premixed with air. CCJ