Awaiting the Much Anticipated Arrival of Micro-generation?

An automotive-based engine – redesigned to be an efficient, durable natural-gas-fired genset – shows promise to become one of the first commercially available micro-generators

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With the Industrial Age came growth, including growth in the size of equipment. With the Information Age upon us, the trend is toward smaller and more efficient. This trend is true in the power generation industry as well, as seen by the recent migration from large mega power plants toward decentralized, on-site power. The latest effort in this small-but-powerful trend is the micro-generator.

Micro-generators can be small, high-speed engine/generator sets or turbine, compressor, and inverters assemblies. They power on-site loads as well as feed power to the grid, and, unlike stand-by sets, operate a large number of hours per year. Their key attributes are size, efficiency, flexibility, low emissions, and low operating cost.

Micro-generators promise to be an important product for the future of the power generation industry. Over the past five years this industry, traditionally characterized by long testing cycles and immense prototyping efforts, has been turned upside down by the media blitz for the micro-turbine (turbine, compressor, and inverter assembly). Micro-turbines are only recently reaching the prototype stage. Unfortunately, there have been many false starts in introducing commercially viable products. With that in mind, any promising technological development is scrutinized and rigorously tested before getting the stamp of approval from the industry. As of yet no technology has garnered this stamp of approval.

A new grass-roots effort

In the back of Terry Kel's automotive lab in Las Vegas, Nevada, a place normally reserved for Steve Force's record-setting top-fuel funny car, engineers from a new company called Engine World have been hard at work. In cooperation with General

Motors, Engine World engineers have designed the Powr/Mastr[1]. This micro-generator is an efficient, clean burning, natural gas fueled, 160 HP engine married with a 100 kW generator to deliver on-site power(see Figure 1). It is designed to operate as a prime power source or as a peak shaver. Ninety-two (92) patent claims are pending on the Powr/Mastr. Many cover modifications to the fuel-delivery system to improve efficiency and reduce emissions (see Figure 2). Inlet air is refrigerated to a constant temperature so that ram tubes can be tuned for maximum acceleration of the fuel air mixture through the cylinders. This not only decreases pumping losses[2], but also improves responsiveness to load steps. Natural-gas-fired units have traditionally been unable to accept large load steps without severe frequency and voltage deviations. By individually tuning each cylinder's fuel and exhaust system, equal fuel loading is maintained on all cylinders. This ensuring that each combustion event is as complete and powerful as feasible, thereby minimizing fuel consumption and emissions. The result is a heat rate below 9,500BTU/kWh[3].

The Powr/Mastr is also equipped with advanced electronics that not only sequence and synchronize the unit, but also coordinate multiple units so that each can operate within its most efficient range. The electronics package contains capacity-management algorithms that monitor site demand and autostart the engine based on time-of-day, demand-charge-avoidance or make-versus-buy criteria (see Figure 3).

Improving durability

With efficiency issues addressed, the next challenge for the Engine World engineers was to stretch the useful life of the engine to 50,000 hours[4]. First, the engineers redesigned the lubrication system by adding a larger sump, changing to pump/gravity-feed lubrication to eliminate splashing and foaming. Next they added an inter-cooler to better regulate oil and water temperatures. These measures, coupled with the even cylinder loading, improve engine life by reducing thermal stresses.

[1] POWR/MASTR incorporates a redesigned General Motors 454 engine, a Stamford/Newage 100-kW generator and advanced electronics from Encorp.
[2] Pumping losses are one of the two main efficiency robbers in an internal combustion engine; the other is thermal losses.
[3] Testing of Powr/Mastr units have resulted in peak efficiencies of 9,000BTU/kWhr. Due to variability of loading 9,500 is used as a conservative estimate.
[4] The effective life of the GM 454 before modifications is 15,000 hours as quoted by General Motors.

Finally, the on-board electronically controlled start system cranks the engine for ten seconds before ignition or fuel is introduced. This ensures the engine is thoroughly lubricated and purged before combustion commences. The unit then warms up at 1200 rpm until the oil and water temperatures rise to acceptable levels. Only at this point is the engine gradually ramped up to rated speed and brought on line. Once on line, the electronic controls synchronize the generator with the local power grid and smoothly ramp to efficient levels of real and reactive power (see Figure 4).

Should a parameter fall out of its specified operating range, an alarm triggers. If significant enough, the generator will automatically separate from the utility and shut down. The alarm is simultaneously transmitted back to a central maintenance facility via an automatic telephone dial out. Whenever an alarm triggers, a pop-up window appears on the maintenance dispatcher's computer that details the problem. If the alarm is not acknowledged within five minutes, an alphanumeric pager signal is transmitted to an on-call technician. Either the technician or the dispatcher can then remotely connect to the site, determine the cause of the problem and take corrective action. Each unit also automatically notifies the dispatcher of approaching maintenance, and shuts down if the scheduled maintenance period is exceeded.

Bringing a complete package to market

The Powr/Mastr, after passing the rigorous engineering cycle, needed an effective method of marketing and support. Marketing to utilities and their subsidiaries is being provided by KN Energy[5]. based in Lakewood, Colorado. The units are offered either for direct sale or via a five-year lease that optionally includes all installation, service, and maintenance within the fixed lease price of $1,500 per month. With this option the customer only pays for fuel and any applicable standby and/or supplemental electricity use charges (See example below). KN Energy is also offering a variety of fuel pricing options that allow the customer to lock in rates or float with the market.

Unless a customer opts to assume the responsibility, Engine World provides all service and installation in a hub style network. Each limited geographic area will have a

[5] KN Energy, Inc. (KNE), is an integrated energy services company with operations that include natural gas gathering, processing, marketing, storage, transportation, energy commodity sales - natural gas, liquids and electric power marketing - and innovative services designed for consumers, utilities and commercial entities. KNE is traded on the New York Stock Exchange under the symbol "KNE."

provider. This local provider handles all services, including the stocking of replacement units. There are no maintenance or parts costs. All costs are inclusive in the full service lease.

A rate based example

The following example is a real-life case study based on a common rate structure for commercial customers within a large metropolitan service territory. The customer's load profile is common for a large commercial, retail store. This commercial customer is currently billed, by the local electric utility, based demand/energy rate during on peak hours and a straight energy rate for off peak hours. The demand and energy component charges for the on peak hours are relatively high while the off peak energy charges are very low. Based on the size of the load and its profile for this customer, the average cost for all energy consumed (on and off peak hours combined) is nearly 8 cents per kWhr (including adjustments). Analysis showed that the optimum solution, utilizing the Powr/Mastr units, would be to operate 4 units during on peak hours, exclusively, in a base load configuration and purchase all off peak energy from the local utility. Table 1 below shows a breakdown of the current monthly energy use and the total estimated energy costs, including natural gas for heating load.

Estimated Energy Costs without POWR/MASTR			
	Usage	**$/Unit**	**Energy Cost**
Off Peak Energy Usage	99,000	$0.0791	$7,830.90
On Peak Energy Usage	96,000	$0.0791	$7,593.60
Gas Usage (Heating)	6,870	$0.36329	$2,495.85
Total Bill without POWR/MASTR			**$17,920.35**

Table 1 – Costs without installation of Powr/Mastr

Table 2 below describes a breakdown of the costs for the same customer site utilizing four (4) Powr/Mastr units during the on peak hours. There is a monthly charge of $1,500 per unit that is an all inclusive lease payment. Engine World provides installation, maintenance and repair, under the lease, and guarantees no more than 72 hours down time on every unit for entire term of the lease. Other charges include standby and supplemental electric service from the local utility and additional fuel usage associated with operating the Powr/Mastr's.

Estimated Energy Costs with Powr/Mastr			
	Usage	**$/Unit**	**Energy Cost**
POWR/MASTR lease	4 units	$1,500	$6,000.00
Off Peak Energy Usage	99,000	$0.02273	$2,250.27
Peak Charge[6]			$994.00
Customer Charge			$40.00
Standby Charge			$98.00
Facility Charge			$299.00
Adjustments[7]	99,000	$0.00237	$234.63
Subtotal			$3,915.90
Franchise Fee/Taxes	$3915.90	8.51%	$333.24
Total Electric Charges			$4,249.14
Gas Usage (Electricity)[8]	9,120 Therms[9]	$0.36329/Therm	$3,313.20
Gas Usage (Heating)	6,870 Therms	$0.36329/Therm	$2,495.80
Total Gas Charges			$5,809.00
Total Bill with Powr/Mastr			**$16,058.14**

Table 2 – Costs with installation of four Powr/Mastr's

The result is that this customer will save an estimated $1,862.21 per month immediately upon installation of the 4 Powr/Mastr units. This equates to a decrease of over 10 percent of the total energy costs for the facility with virtually no capital outlay and very little risk. However, an equally important result is that the customer's reliability has been significantly improved by having enough generating capacity on site to supply the facility during outages from the local electric utility. This type of savings and improvement in reliability should make most consumers conclude that micro-generation has arrived.

[6] Peak Charges are incurred due to the load profile of the facility not being totally flat, and having a demand slightly above the capacity of the units for short periods of time.

[7] Adjustments are Public Utilities Commission approved variability due to fuel costs and other system issues.

[8] Natural Gas charges are based on bulk rate provided by KN Energy with distribution charges from People's Gas. Although customers are not required to purchase gas from KN Energy, varied and attractive gas pricing options are available from KN. The price used is a conservative estimate.

[9] Again, the assumed efficiency for these calculation is 9,500 BTU/kWhr. This is a conservative estimate from the verified efficiency of 9,000 BTU/kWhr, and any efficiency above this level will result in additional bottom line savings.

Although the power industry has not fully embraced any specific micro-generation technology yet, commercially ready products like the Powr/Mastr are going to change this over the next couple of years. Deregulation and the spread of summer time power shortages will continue to push the demand for localized solutions. If, like many in the industry, you have been awaiting the arrival of micro-generation, 1999 promises to be the year when the concept becomes reality. Whether turbine or reciprocating engine, the small-but-powerful micro-generation trend has arrived.

About the authors

Doug Salter is the Vice President of Engineering for *EN*CORP, Inc. Mr. Salter has over 15 years experience in the development and application of power generation technology. Mr. Salter spent seven years as a nuclear power plant supervisor for the US Navy and holds a B.S. in Electrical Engineering from the University of Colorado.

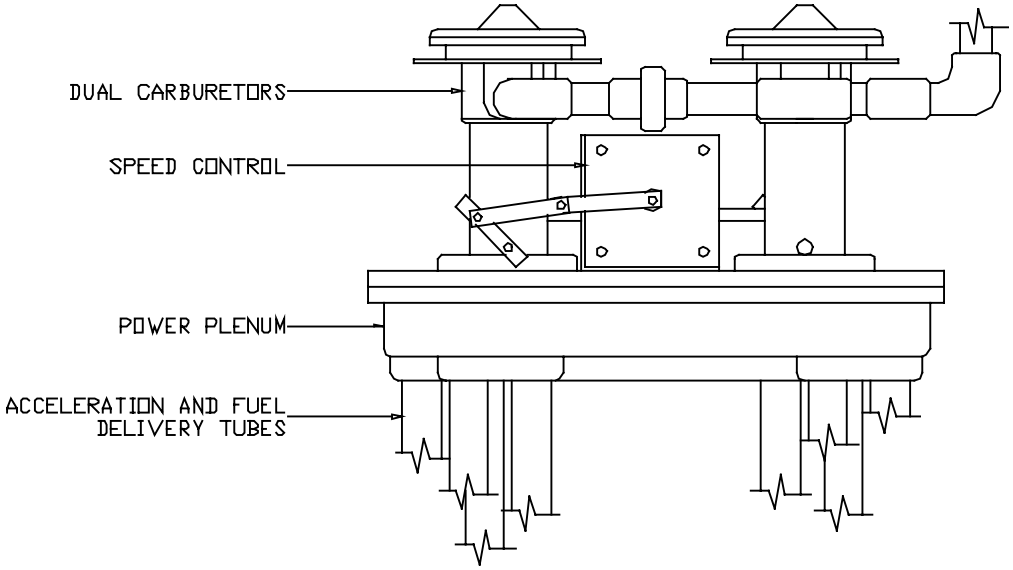
Mr. Pirozzoli is the Director for Distributed Generation at KN Energy. He is presently responsible for the development, support and sales of a wide range of commercial and industrial products and services, including distributed generation technologies and wrap around services, targeting the utility market segment. Mr. Pirozzoli holds a B.S. in Engineering from the University of Wisconsin and is a Registered Professional Engineer.

Phil Meisinger is CEO of Engine World. He earned a B.S. in petroleum engineering from Texas Tech University and has over 20 years experience in engine design.

***EN*CORP has been a member of EGSA since 1994.**

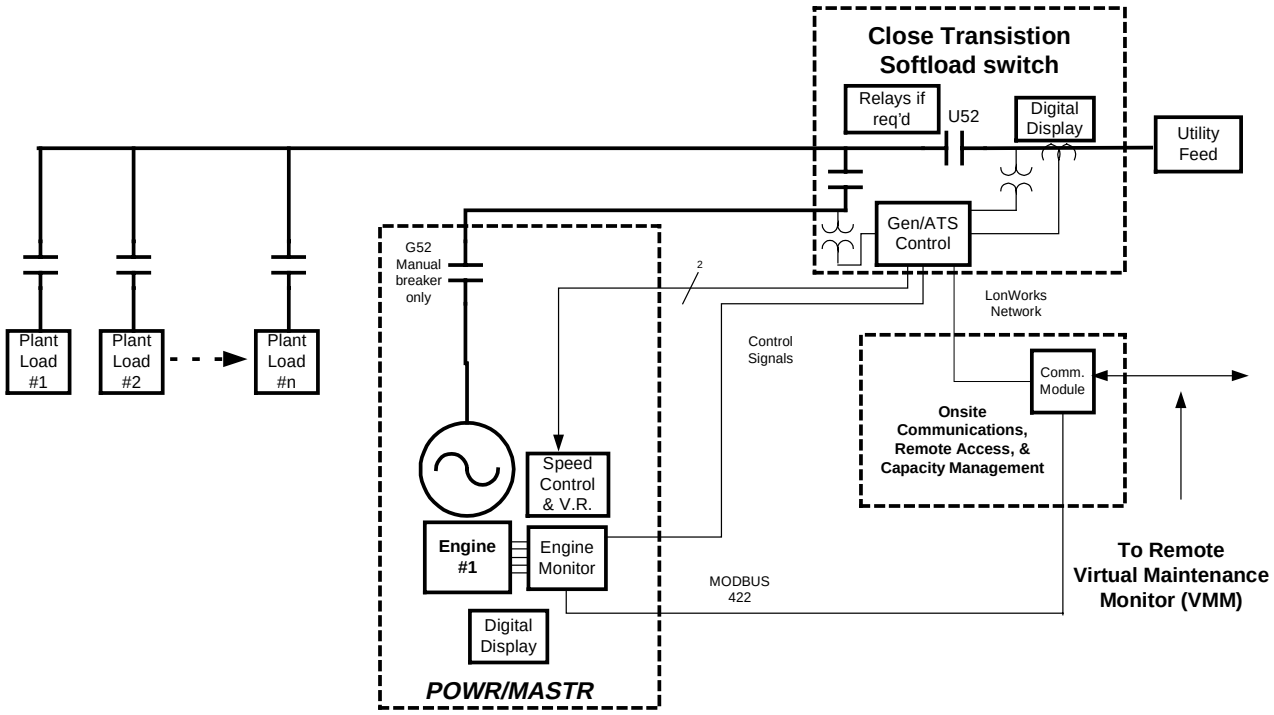
(**Figure 1** – picture of unit on trailer)

The engine/genset fits into a 6' high x 8' long x 5' wide container with four adjustable legs and a removable set of wheels, ideal for quick transport and relocation. Four attached eyelets enable it to be easily hoisted atop buildings and into other difficult locations. Once on-site, it requires only natural gas and electric hookups.



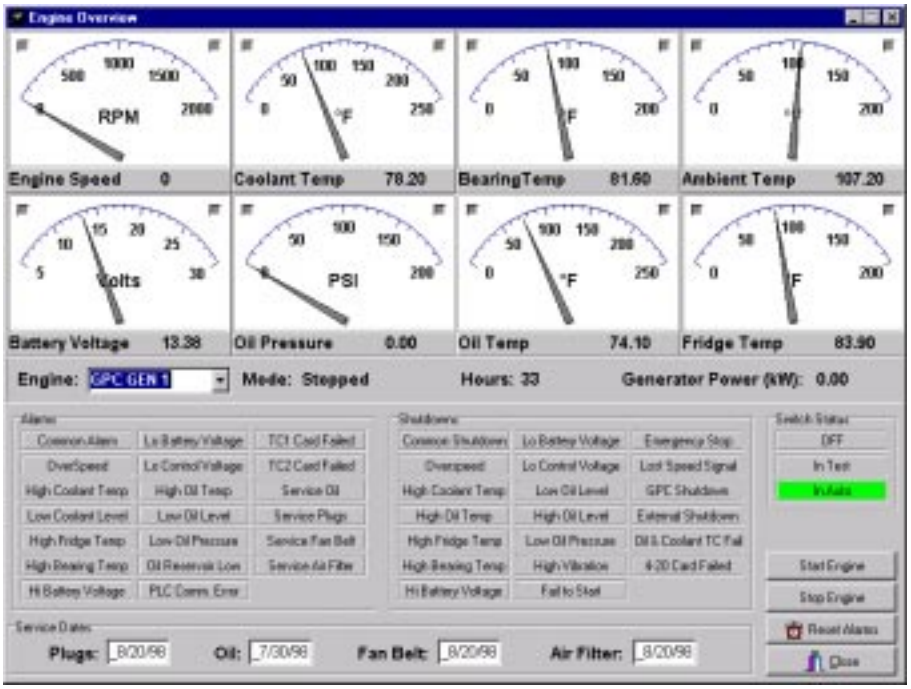
(**Figure 2** – fueling system drawing)

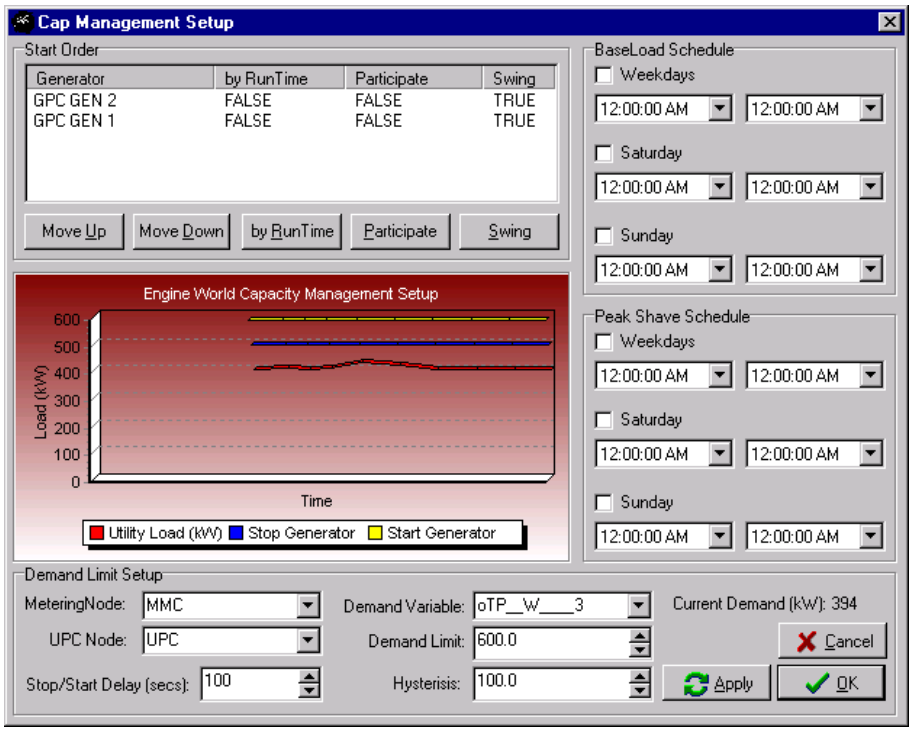
The naturally aspirated engine – equipped with special heads, ram tubes and exhaust pipes – has been designed and tested to provide an extremely high-velocity air/fuel mixture evenly to the eight cylinders. Each inlet tube and exhaust pipe has been precisely sized to minimize flow resistance.



(**Figure 3** – single unit system block diagram)

The algorithms in the electronics control package are flexible and remotely configurable to meet the changing rate structures expected in volatile, deregulated markets.





(**Figure 4** – screen shot)

Oil, water, generator bearings, inlet air and electrical output are all continuously monitored to ensure proper operating characteristics.