Innovative Naples Generator Design
Replaces Large Units in Temporary Power Restoration
Following Hurricane Wilma

Introduction

Utilities in Florida rely heavily on the electric infrastructure to power water and wastewater treatment plants and facilities such as storage facilities, repump stations and lift stations. Without power, water supply and wastewater treatment, both essential and critical needs for maintaining quality of life and public health are severely impacted. With four of Florida's most powerful and damaging hurricanes occurring in a span of two years, timely restoration of electrical power essential for maintaining these critical utility facilities in a few days can no longer be taken for granted. When power line devastation occurs in wide swaths of heavily populated areas, restoration of power can take several weeks or longer.

When electric power is lost, and in most cases, utilities must quickly turn to electric generators to keep critical water and wastewater (W/WW) facilities operating. Although every medium and large Florida W/WW utility will maintain a number of stationary and mobile generators, the number of generators required to service every W/WW facility and lift station is enormous, impractical and not necessarily the most efficient means of providing temporary service. The number of lift stations alone in a mid-sized Florida city can exceed 500 and in several larger cities the count can be in the thousands.

Hurricane Wilma damaged a considerable amount of electric infrastructure, with the most severe damage occurring on both the East and West Coasts of South Florida. In the aftermath of a storm of this destructive power, W/WW utilities for the first time worked through a coordinated network called FlaWarn. FlaWarn provided a State network for identifying utility W/WW needs and provided a mechanism for organizing and sending resources quickly to the areas in most critical need. In some instances, generators were not only provided by the 40 Florida utilities that assisted with this effort, but by FEMA working through the Army Corps of Engineers who provided large commercial 3 phase generators through the FlaWarn network.

The most significant need in the aftermath of Hurricane Wilma was the transport and installation of these large mobile generators. Most of the generators came from W/WW utilities in North and Central Florida not affected by the Hurricane who sent equipment and manpower to W/WW utilities in South Florida. The FlaWarn network continued to function several weeks after the storm had passed ensuring that the resources went to areas most in need.

Providing this type of assistance after a hurricane is the most common method of providing timely temporary restoration of power to W/WW utilities. This requires that W/WW utilities transport and install large generators from remote areas. These generators typically range from a smaller 240/480V, 40KW unit to units in the 240/480V, 125KW class. Generators in these sizes are extremely flexible and can power up the

majority of the motors that are used in W/WW utility installations. These generators typically require a truck in the 1 ton range for hauling and must be matched to power needs that are appropriate, delivered to the site and connected in the field by an electrician experienced with W/WW installations.

Large Commercial Generator Used to Power
City of Kirbyville Texas Repump Station
In aftermath of Hurricane Rita

The work accomplished by FlaWarn was the first coordinated W/WW utility effort on this scale ever used for a major hurricane. It was accomplished by utilities working cooperatively together and sharing considerable resources. This was a monumental task involving 40 Florida W/WW utilities and over 200 Central and North Florida professional. For this reason any system that can expedite the installation of generators at W/WW facilities and minimize the need for their lengthy transport and requirements for specialized personnel for sizing and field connecting is highly desirable. The ability to reduce the need for outside resources and to allow available scarce resources to be moved quickly to those utilities most in need provides the greatest advantage offered by these recommendations.

Innovative Generator Design Developed by the City of Naples

The City of Naples is a mid-size Florida city, located on the Gulf of Mexico in South Florida, the farthest Western point on Alligator Alley. The City of Naples, Department of Public Works, is responsible for providing water service to a population of 65,000 people. The City's Water and Wastewater Division is responsible for the operation of a 30 MGD Water Treatment Plant, a 10 MGD Wastewater Treatment Plant, 115 lift stations and 51 water production wells. In 2004, the City listed 12 standby generators as critical assets. This accounted for backup capacity for about 10% of the City's lift stations in an electrical power outage.

In the aftermath of Hurricane Charley that hit the area in 2005, City W/WW personnel under the direction of Robert Thomas, Wastewater Manager, began experimenting with the use of Variable Frequency Drive (VFD) control systems for converting electrical power from small, single phase generators, to three phase power, the type of power required to supply the City's lift stations. It was quickly determined that the much smaller generators, in the ranges of 5 KW to 15 KW could be used in combination with the VFD to provide power to motors in the 5 HP to 20 HP range. Additionally, Mr. Thomas determined, that the horsepower requirements for most pump units at the City's lift stations were typically significantly oversized. With the VFD control unit, Mr. Thomas was able to provide sufficient power at ratings of up to a 25% less than the motor size. For example a 20 horsepower motor could be operated successfully at 15 horsepower, while still providing the needed pumping energy to keep the station in a full pumping mode.

Based on these initial trials, the City constructed a mobile 15 KW trailer mounted generator, a VFD and a level transducer. The transducer can be placed in the wet well replacing the need for the lift station controls. These controls are housed in a control panel that is frequently damaged hurricane events. Furthermore, this smaller trailer mounted unit, can be easily transported using a ½ ton pick-up or any utility vehicle with a ball type hitch. Electrical hook-up is a simple four-wire set-up that the City is in the process of converting to a standard 30-amp receptacle, similar to the one used for an electric stove connection in a home. This generator unit is fully capable of moving from one lift station to another, allowing the lift station's wastewater to be evacuated and using the wet well and pipeline storage to refill, while moving it to another lift station or stations rotation, much like current pumper trucks now used in these kinds of emergencies.

This application of VFDs in combinations with smaller generators for use with lift stations and small water wells in the 5 horsepower to 20 horsepower range is a significant breakthrough when compared to existing generator applications. Smaller generators in the range of 5 KW to 15 KW are a stock item at building supply stores such as Lowe's and Home Depot. The cost of a three phase generator in the 20 KW range is over $13,000 or approximately 10 times the expense for 15 KW single phase generator that can be used in this application. And there are other advantages.

Assessment of the Potential Use of the Naples Solution (NS) to Other Utilities

To determine the potential for using the NS for other utilities, we must first go back to Naples and examine their hurricane response. Like other utilities in the path of Hurricane Wilma, Naples found themselves with more than 90% of their system without power. This was met with the deployment of 30 single phase/VFD controlled generators to lift stations in the 5 HP to 20 HP class. One pick up truck can easily transport 6 of these small generators its bed and one employee can deploy them to critical need stations, providing a hook up using a standard plug. Transport of 6 commercial generators South, for a North Florida utility would be a significant undertaking, requiring six special utility vehicles, 6 drivers and an additional 6 personnel for equipment set up and installation.

The City of Naples, as directed by Mr. Thomas, demonstrated the use of this very innovative generator alternative. It worked in the aftermath of Wilma, in the very place where she made landfall.

The question quickly becomes, how effective would the use of the NS be for mid-sized or larger utilities that may require larger equipment? To answer this question a typical mid-size North Florida W/WW utility system was analyzed to determine applicability. The analysis was also used to expand it to the applicability of other W/WW utilities in the aftermath of a significant hurricane event with some very surprising results! The detail of the full analysis is included in the next section.

Analysis of Typical Mid-Sized Utility for NS Application to Other W/WW Utilities

This analysis assumes that emergency conditions are such that complete loss of power occurs for an extended period exceeding 3 days. The analysis assumes that lift stations that utilize pumps 20 HP and smaller are of the duplex variety. A duplex lift station is a lift station that includes two pumps, with one pump designed to handle incoming flow with the other pump out of service. The analysis considers that in an emergency situation a lift station smaller than 20 HP (uses two, 20 HP pumps) can handle incoming flow for an extended period of electrical outages with an emergency generator using only one of the two pumps available at the station.

The data that was used for this analysis was taken from Gainesville Regional Utilities (GRU) a mid-sized North Central Florida wastewater utility with approximately 50,000 wastewater customers. The generator requirements that have been developed are likely conservative, that is the percentage of smaller stations in the GRU system is likely less than that of similar systems in coastal South Florida where the terrain is flatter and the water table is higher, dictating a higher number of smaller lift stations. The numbers developed in the analysis are thus conservative and for most systems the number of generators that are required following a hurricane and long-term power outage can be reduced further.

The following table illustrates the lift station distribution for Gainesville Regional Utilities W/WW System:

Table 1

Lift Station Data
Gainesville Regional Utilities

Size of Pump Unit (HP)	No. Of Lift Stations in Category	% Of Entire System for Lift Stations	Rolling Average % ↓	Number of Permanent Generators	Rolling Average Perm. Gen. ↑
0 to 5 HP	57	***37%***	37%	0	06%
7.5 HP	1	***1%***	38%	0	11%

9.4 & 10 HP	46	***29%***	67%	1	11%
15 HP	3	***2%***	69%	1	15%
20 HP	32	***21%***	90%	1	14%
30 to 40 HP	5	3%	***93%***	***1***	***35%***
47 HP	10	6%	***99%***	***4***	***42%***
Above 50 HP	2	1%	***100%***	***1***	***50%***

The numbers in blue are a rolling average from the smallest station to the largest. The numbers in red are a rolling average from the largest system to the smallest. These figures were used to develop sensitivities for how lift stations might be serviced by generators using those owned by the Utility. From the above table several facts can be discerned:

1. **Approximately 90% of the GRU lift stations use 20 HP and smaller pumps.**
2. **Only 10% of the GRU system (17 stations) consists of lift stations that require generators that are larger than 30 KW.**
3. Of the 17 lift stations that are larger than 20 HP, 6 have permanent generators at the lift station site. If we were to include GRU's 6 portable generators, then 71% or 12 of GRU's 17 lift stations that use 30 HP pumps and above, would have auxiliary power in an emergency situation.

In the case of a system such as illustrated above, the NS would meet 90% of the systems need. Combined with existing resources, NS is substantially capable of handling an extended power outage resulting in major hurricane damage!

For most all mid to large utilities this case would be directly applicable!

Using VFD Controller s for Small Generator Application

The NS utilizes an Altivar 31, Adjustable Speed Drive Controller, manufactured by Telemacanique. The VFD comes in various stock sizes that handle motors in the 3 HP to 10 HP sizes. A newer VFD model rated at 20 HP and manufactured by Square D, model ATV31HD15M3X, came out this year and must be special ordered. It is priced around $750. In ordering a VFD, be certain that the unit is configured to convert single-phase input to three-phase output. It is recommended that the larger VFD be used because it is downward (smaller horsepower) compatible.

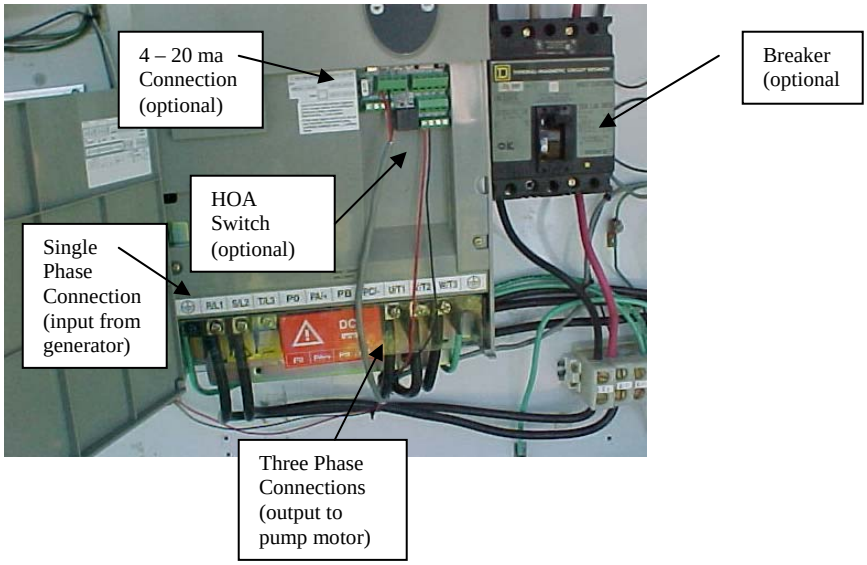
VFD units are extremely versatile and can be used in a wide variety of applications. The basic set up requires two input connections from the single-phase generator and three output connections and a ground connection. The VFD can be connected directly to incoming three phase breaker at the lift station if it is desirable to use existing lift station

controls. For this set up the second motor-pump is de-energized at the breaker to protect the VFD from an overload where both motors are running.

Setting up the VFD unit requires only a few settings to account for the Full Load Amperage draw required by the motor. The VFD may be set to ramp up in speed to prevent high starting amperage. The unit also has a setting for current overload protection.

For installations where the VFD is used directly to power a motor-pump combination the speed of the pump is reduced to meet flow demands at the lift station. Adjusting the frequency of the motor to below 60 hertz controls the speed or pumping capacity of the pump. Full speed is 60 hertz and half speed (50% pumping capacity) is approximately 45 hertz. The speed that the motor runs is directly proportional to the horsepower draw. This allows smaller generators to be used to power larger motors while still evacuating enough wastewater from the lift station to prevent spilling.

The VFD has connections for installing a breaker, fuse protection and for a standard HOA switch as well as a connection for a 4 – 20 ma controller if these are desired are all provided. Input and output connections for a typical Altivar 31, VFD/single phase generator connection is shown below.


4 – 20 ma Connection (optional)
Breaker (optional
HOA Switch (optional)
Single Phase Connection (input from generator)
Three Phase Connections (output to pump motor)

Wiring Schematic for Single Phase to Three Phase
Conversion using Altivar 31 VFD

The City of Naples has found it convenient to house the VFD in a cabinet attached to the generator to protect the unit from the weather.

Future plans call for permanently installing VFDs at smaller lift stations, using them to reduce energy requirements. The payback period in electrical cost savings compared to the cost of the VFD, are projected to be less than 3 years for a typical station. Because the VFD can better match the flow conditions, motor stops and starts are reduced extending the service life of the motor.

NS Comparison to Existing Generator Use
For Lift Stations 20 HP and Smaller

NO.	**NS (Small 1 PH Generator & VFD)**	**Conventional 3 PH. Generator**
1.	Generator Cost and VFD cost less than $2,500	Generator for 30 KW Cost $13,000 to $15,000. Larger units can approach $30,000.
2.	Generators in 5 HP range available locally.	Generator for 5 HP station special order large trailer mounted item.
3.	Several Small generators can be transported in the bed of a conventional pick up truck.	Each generator must be pulled by a recommended ¾ ton vehicle.
4.	Generator set up can be performed by maintenance personnel.	Generator set up requires the services of a commercial electrician
5.	Generators run on gasoline that is generally in adequate supply locally.	Generators run on diesel fuel. Obtaining fuel and fueling in emergency situations can be difficult and require fueling vehicles
6.	VFDs are extremely versatile and can handle ranges of smaller HP sizes.	Generators costs vary slightly in smaller sizes, thus larger sized units are frequently used at small lift stations.
7.	Small generators are portable and can be handled easily by two employees	Large generators typically require crew of two to three people to set up and require special electrical skills
8.	Small generators require minimal maintenance and can be considered depreciated in 3 to 5 years	Large generators require considerable specialized maintenance, frequent exercise (recommended monthly under load) and require protected storage. Service life is 20 years.
9.	Generators can be obtained and deployed easily by affected utility	Transport of large generators to emergency areas requires outside crews to housed in the

		areas for extended periods
10.	Emergency response is immediate protecting health and meeting needs of citizens for water and wastewater service	Emergency response lags as assessments of areas and movement of equipment from long distances progresses.
11.	Generators can be carried through back yards and placed in areas that are inaccessible to utility vehicles	Utility vehicles cannot access some areas immediately after storms because of the amount of debris and trees that are knocked down.
12.	Use of these generators frees larger units for deployment elsewhere	Large generators supply is limited and priority application results in some areas waiting extended periods for help.

Lift Station 207
City of Sunrise in aftermath of Wilma

Access to this lift station is severely impeded in the aftermath of Hurricane Wilma.
Lift Stations such as these can be operated with the use of portable generators like the one shown in the installation below.

Dave Hutchinson, FRWA assists Greg Graham, City of Sunrise, in installing a single-phase portable generator/VFD combination to power a small three phase lift station.

Small generators like the one shown at right can be easily transported by two employees
and quickly deployed to a residential lift station site. The VFD unit can often be placed
directly inside existing lift station control panel as shown above.

Conclusion and Recommendations

The NS is certainly applicable for a large number of Florida Utilities and would improve the ability of W/WW utilities to respond to a major hurricane in the future. The greatest advantage to the NS solution is for the smaller utilities in Florida that do not have the resources of the larger communities but provide utility services to many Florida residents. There are approximately 7,000 water systems in Florida. If the statistics generated above are applied, there are some 6,000 locations that could benefit from this innovative technique. The systems works and was applied not only in Naples, but was used in several W/WW installations in Broward County and in the City of Sunrise following Hurricane Wilma.

Florida Rural Water Association will be working with these systems to encourage them to use this technique in providing water immediate after a destructive hurricane. The cost of these VFD/generator combinations is within most small utility budgets and it is anticipated that the concept will be used extensively in the future.

Florida Rural Water Association will be providing the design for these units on its WEB Site at frwa.net.

Bibliography

Bob McVay is a Registered Professional Engineer and was formerly the Assistant General Manager for Water and Wastewater Systems for Gainesville Regional Utilities.

Bob has spent considerable amounts of time in 2005 in hurricane restoration efforts assisting water and wastewater utilities in Mississippi, Texas and Florida. He is the full time water trainer for Florida Rural Water Association.

The Executive Director of Florida Rural Water Association, Gary Williams, is also a steering committee member of FlaWarn, the W/WW utility coordinating group referred to in this paper. Florida Rural Water Association has 1,476 members with W/WW utilities serving a population of over 9 million people in Florida.

Bob Thomas is the Manager of the Wastewater System for the City of Naples and has spent considerable time in building, installing and troubleshooting the VFD/Generator units described in this article. Bob provided 7 operating VFD/Generator units to Florida Rural Water Association who used the equipment in various utility locations in South Florida in the aftermath of Hurricane Wilma.