White Paper

Powering TETRA

Table of Contents

Powering TETRA Systems for Resilience or Network Expansion

1 Introduction

The impact of the loss of power during an emergency has been clearly demonstrated over many years. For example, in 1998/9 Eastern Canada was hit by severe ice storms which brought down miles of power lines which took weeks to replace. Hurricanes and storms have repeatedly hit the southern states of the USA with much the same effect on power transmission and distribution. Europe and Asia have been hit with disasters such as floods, earthquakes, and of course the Tsunami in the Indian Ocean.

Emergency situations are not confined to natural disasters. Terrorist attacks or power infrastructure failures could also cause extended periods of power outage.

In emergency situations there may be a need to establish a temporary communications network in a location where none exists. Such situations could be in a refugee camp, or emergency housing following a disaster in a remote location. In such situations there may be a shortage or absence of power for the communications system.

It follows that emergency communications elements such as TETRA Base Stations, Switches, backhaul, and other network infrastructure must remain in operation during these times. The First Responders and other emergency staff will be relying on TETRA for communication as the critical element in the management of operations. TETRA must be the most resilient communication system and should withstand all types of disruption be it vandalism, severe weather, or power distribution failure. These conditions may lead to a loss of electrical power to the sites and a resilient TETRA system needs to be self-powered for days, without the need to replenish fuel or batteries.

There are regions of the world where grid power is not available for 24 hours a day and outages of an hour a day or more are common. In these cases the back-up power system is regularly used and it follows that it should be capable of long operational periods between maintenance and also offer low operating cost per kW/Hr.

2 Alternative Power Solutions for Mains Backup

Achieving this today requires the provision of self-starting generators or a very large battery bank. Such systems are well proven, but they have disadvantages. In particular, batteries do not respond well to long periods at full charge, and their life is also limited in hot climates. Lead Acid batteries also have a poor environmental impact and have to be recycled with care. Diesel generators are a comparatively cost effective means of providing back-up power, but for high dependability a twin set may be required. Diesel generators also advertise their presence with noise, fumes, and smoke, the fuel and the generator itself is a readily trade-able asset and therefore a target for theft.

Alternatives to the use of diesel generators are now available and proven. LPG powered generator sets offer an improvement in emissions and efficiency and the fuel is less easy to steal. However the availability of fuel cell

technology has created a major step forward in terms of alternative power for back-up. Fuel cells are inherently more efficient than internal combustion generators and are now being widely deployed as power back-up solutions in banks and IT facilities.

The following table compares the Proton Exchange Membrane technology and LPG and Diesel generators.

	Diesel Generator	LPG Generator	PEM Fuel Cell
Start-up	Reliant on electric start, prone to problems in low temperatures	Reliant on electric start, specialist equipment required for fuel re-supply	Fast starting
Efficiency	Low	Low	Medium
Emissions	CO2, SO2, + soot	CO2	H2O
Acoustic and visual signature	Poor, noisy, vibrations	Low, clear exhaust, vibrations	Very low audio and vibration signature
Capital Cost	Low to Medium, depends upon whether a twin set required. Security fencing will add to capital cost.	Medium	Medium
Operating cost	Low, if diesel fuel is easily available and site is easy to access.	Slightly higher cost than diesel LPG	Higher cost of Hydrogen is offset by higher efficiency

PEM fuel cells are now a viable alternative to generators, and are particularly well suited to situations where the periods of mains failure are infrequent and generally of a short duration. This is because a PEM fuel can remain dormant for very long periods and then start up reliably and quickly. Hydrogen has to be stored at high pressure to achieve an acceptable energy density, and if a PEM fuel cell is used for extended periods then replacement cylinders will need to be supplied. The low noise of a PEM fuel cell will also be well suited to installations on top of buildings or in confined situations close to working or even living areas. PEM fuel cells are powered by hydrogen which must be of good purity as impurities will degrade the membrane and shortening its life. The use of the PEM fuel cell technology is therefore recommended for accessible locations in regions where the supply of hydrogen can be guaranteed.

The only emission from a PEM fuel cell is water vapor, and so in cities and other locations where there are incentives for low emissions or penalties for high emissions, then the technology is highly desirable.

Another technology moving into regular use is the combination of a PEM Fuel Cell with a Reformer. In this case an additional unit is provided with a hydrocarbon/water mix which is processed to extract the hydrogen which is then passed into the fuel cell. The hydrogen from the hydrocarbon fuel (such as ethanol) and the water is extracted, the carbon is combined with atmospheric oxygen and vented as carbon dioxide. The primary advantage of this system is that it can operate for extended periods of time as the liquid fuel has a high energy density and a large fuel tank can be provided at a modest cost. Clearly, such a system emits CO2 and therefore cannot claim the green benefits of a hydrogen PEM system. However ethanol can be generated from renewable sources and so such a system can be carbon neutral. In addition the fuel can be manufactured in emerging

nations from biological waste. The particular application envisaged for such a system could be in a location where several hours a day of backup power is required, or where a highly critical base station must be able to operate for several days without mains power and without fuel replenishment.

3 Examples of Possible Deployments

It becomes clear that many factors need to be considered in the selection of a backup power system for a mission critical network, and a site by site evaluation may be necessary. Let us consider some examples.

A TETRA base station is to be located on the top roof of a city office block. Power outages are infrequent and rarely last more than one hour. Access to the site is easy and hydrogen cylinders easily fit into the service lift. There are offices immediately below the location where the base station is to be installed and a low acoustic signature is essential. In this case a LPG powered generator or a PEM fuel cell should be considered. The final choice will depend upon the reliability of the solution and the duty cycle. The PEM fuel cell wins if the duration of outages is short and infrequent, the LPG powered generator if absolute reliability can be lower and these are likely to be extended periods of power outage (because of the higher energy density of the fuel). However if acoustic signature requirements are low then the PEM/Reformer combination becomes attractive, and the water/ethanol fuel is safer and easier to handle.

A TETRA base station is to be installed in a city or community where mains power is intermittent. Outages are regular and may often last for one hour or more. Generally the diesel generator will be a cost effective solution, and the audio and gaseous emissions may be acceptable. However there are many such locations where security is the dominant factor and the fuel and generator set are vulnerable to theft; the noise and smoke simply advertise the presence of two highly tradable assets. LPG powered generators will partly overcome these drawbacks but LPG too is a tradable asset and the fuel and set remain at risk. One possible solution might be the use of piped gas if available, provided the LPG Generator set is highly secure. PEM generators may not be suitable as hydrogen re-supply may be costly and inconvenient. The PEM/Reformer becomes attractive as the fuel cannot easily be used for domestic purposes and the high energy density and low flammability make handling safer and more convenient. These fuels are also easier to manufacture locally and are carbon neutral.

4 Alternative Power Solutions for Off-Grid TETRA Solutions

TETRA systems have mainly been deployed in locations with mains power over the last decade, but increasingly they are required in locations where conventional mains power cannot be supplied, or only at extreme cost and high vulnerability. Working with the GSM Association and the operator MTC Motorola has pioneered the use Wind and Solar Energy to power a GSM base station in Namibia, Africa. Valuable lessons have been learned from this successful deployment, together with the establishment of a partnership to plan and assist in the deployment of further sites for GSM, WiMax, or indeed any mobile communications technology. These benefits can be passed on to the TETRA deployment program in all regions of the world.

With global manufacture of both wind and solar systems accelerating the cost/kW declines and the solutions mature, making these affordable and reducing pay-back times.

As with any such solutions the viability in both technical and financial terms has to be assessed on a site-by-site basis. The main factors to consider are the weather conditions (wind and sun), the accessibility of the site (in

terms of delivering conventional fuel for generators), and the possibility and cost of the supply of mains power. Simply put, the case today is that wind/solar solutions are cost effective for a site several kilometers from the nearest mains supply, or which is costly and inconvenient to regularly visit with a fuel supply vehicle (or boat). Examples include, islands near harbours and inlets where coverage is required. Parks and areas where mains lines are not permitted. Rural areas in emerging countries. Isolated areas in developed nations such as mountainous areas or long highways.

Other considerations need to be added to the planning process to ensure that such systems will be suitable for TETRA.

The availability targets for TETRA will be higher than for public mobile services. As wind and solar energy are dependent upon meteorological factors, the planning process will have to take into account the most extreme and unusual weather conditions. Highly unusual long periods of poor sun and wind energy will be a challenge, and whilst drop-out of the site for a few days every few years may be acceptable in public systems, this is not the case for TETRA. Fortunately the same fuel-cell technologies described above can be added to a wind and solar site to provide the power during unusual conditions, and may be partly funded by savings in the size of the battery bank or even the size of the wind and solar systems themselves. The planning tools developed jointly by Motorola and it's partner Power Oasis are essential to ensure that the viability of these solutions is reliably established and that an optimum specification is designed.

A final observation regarding off-grid deployments. A solar/wind/fuel cell power systems would be a valuable addition to a mobile TETRA Base station (often referred to as a Cell-on-Wheels or CoW). In particular in a relief or emergency situation a TETRA base station with a combined power system using solar/wind/fuel cell solutions could be assembled onto a standard ISO container for rapid deployment. The win and solar solutions would be mounted externally on the container and the Fuel cell in a special compartment at one end. The Base Station and other equipment such as radio backhaul would be installed inside, together with computers and other equipment to act as a command centre for relief operations. Motorola showed a concept fo such a system at the Mobile World Congress event in February 2008 and the unit can be viewed at the Motorola location in Swindon, UK.

5 Continued Research

Motorola established the viability of a wind and solar solution for Mobile Base Stations in a research program in 2005. Since then the exploration has continued and work is underway on the evaluation of other power related technologies.

For example, power storage is a critical element in the efficient use of power, particularly for on-grid backup or off-grid wins/solar solutions. Today's battery technology is costly and also degrades in hot climates. If a reliable and cost effective power storage system can be found then regular power loss lasting hours could be compensated without the use of generators. In remote off-grid applications the excess power from wind and solar power systems could be stored for long periods to cover unusual weather situations. Reflow batteries offer such benefits and scale easily to store large quantities of power. Motorola is evaluating these for use in Mobile Telecommunications.

The use of Water Power goes back to the beginning of recorded history, and is widely used for MegaWatt generation today. In areas where there is an abundance of such potential in the kW class, the use of comparatively simple technology could provide power for remote mobile technology base stations as well as isolated communities. Once again Motorola is actively evaluating the possibilities in this area. In regions with significant seasonal variations the combination of water and solar power could provide year round supply through both wet and dry seasons.

This paper has focused on powering the base stations for TETRA and other mobile technologies. However as fuel cell technologies mature their application to handsets or handset charges becomes viable. Motorola has a research program in place to determine the optimum technology and viability for fuel cells in mobile handsets. In addition the possibility of fuel cell powered chargers has been established with the construction of a prototype. These solutions show promise, and can be brought to the market as the technologies reach the required cost and reliability targets and the demand justifies production.

6 Summary

The solution to the puzzle of power is to accept that no one solution applies everywhere. Local conditions such as weather and also the social and industrial infrastructure will determine the design for the power system right down to the site level. This is true for TETRA as it is for other mobile systems.

The difference is resilience and availability. TETRA has to remain working when local or national infrastructure have been compromised, in fact these are the times when it is needed the most. Some TETRA operators are selecting critical Base Sites and adding additional communication backhaul links and power supply to ensue that these are highly-resilient locations. Combined solutions will be needed in many cases to ensure the very high availability requirements for TETRA as a mission critical communications service.

Fuel Cells, and Wind and Solar Power have proved themselves in other industries as dependable, reliable and robust. Banks, computer centers, oil rigs, exploration stations have all made use of one or more of these technologies and the communications industry is now following. Motorola and its partner's leadership in this area can now be applied to the TETRA networks to ensure the cost effective and resilient service that will be needed for the next decade.

7 Case Study - Motorola and the SINE Network in Denmark

On behalf of the Danish Government, DBK (Dansk Beredskabs Kommunikation, of which Motorola is a majority share holder) is constructing and will operate the TETRA network and will provide service to Emergency and Public safety agencies across the country. Motorola has worked with Dantherm Power to develop a hydrogen fuel cell powered TETRA base station to be deployed in over 100 locations in Denmark. The fuel cell will power the TETRA base station in the event of the loss of mains electricity, and will have a very low acoustic and environmental signature. The base station is therefore ideal for installation on the roof of buildings without impacting on the environment of those below or nearby. Motorola has taken a consistent lead in the use of alternative power solutions in this and other mobile communications technologies to bring cost, operational, and environmental benefits to the operators and end users.