Condition Based Maintenance of Lead Acid Batteries and Environmental Responsibility

By

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Abstract

The increase in demand for electrical energy is putting pressure on outdated utility infrastructures and services at the same time that advances in business operations are requiring stable and sufficient sources of power for sensitive operations.

A key component of the electrical grid is energy storage and lead acid batteries remain the most cost effective solution. The efficient and prudent use of lead is at best difficult at a time that lead acid batteries are being called upon to provide backup power for critical power applications. This study seeks to use lead acid batteries efficiently thereby reducing the amount of lead acid in our environment.

The research consisted of a case study of US electrical power substations, an integral part of the power grid. The case analysis compared traditional maintenance practices of lead acid batteries versus the use of battery condition monitoring. There is a strong business case to be made for investing in condition monitoring to manage the battery assets within power substations. This will ensure that the batteries will function when required.

The case study demonstrated that once condition monitoring was installed the number of preventative maintenance visits to a remote site was reduced by 85% with a commensurate reduction in the number of medium duty trucks on the nation's roads. The avoided CO2 emissions presented a compelling argument for condition monitoring.

Condition monitoring and the resultant condition based maintenance will drive infrastructure reliability higher and result in the more efficient use of lead acid batteries with the added benefit of CO2 reductions. There are hundreds of other applications for

this technology and with strong management buy-in it is possible to overcome the resistance to change from traditional maintenance practices.

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Section 1.0 Introduction

The increase in demand for electrical energy is putting pressure on outdated utility infrastructures and services at the same time that technological advances in business operations are requiring stable and sufficient sources of power for sensitive operations. In contrast to the rapid growth and development in other market sectors, the capacity and reliability of the US power grid has evolved little in the last 50 years. Transmission and distribution systems have only grown half the rate of total demand for electricity, and utilities and other entities have not improved the situation by consistently fighting incentives for development and investment in alternative energy resources.

In the meantime the digital economy is simultaneously demanding improvements in the quality of power. Digital equipment requires stable power and even the smallest interruptions and distortions have considerable impact on business operations for telecommunications, hospitals, manufacturing facilities, and other highly computerized environments such as data centers.

This trend has created exponential growth in the energy storage market and lead-acid batteries remain the most cost effective. The concept of using batteries for load leveling and peak shaving has been known for decades-only recently have these systems become commercially viable. Load leveling and peak shaving has led to more reliable electrical systems and improved service to electric utility customers. In addition, lower maintenance batteries and the availability of methods to predict costs and benefits have made battery energy-storage systems more attractive.

In recent years, environmental concerns have also played a role in the provision of utility power, with more public resistance to the construction of any new power plants whether they are fueled by natural gas or coal. This trend along with pollution controls has created a dynamic environment for electric utilities to operate in.

The challenges of critical power today are to ensure the availability and provide predictive analysis to prevent potential faults from affecting mission-critical operations. Some extremely exigent industries require even extending this responsibility beyond the building itself to consider power generation and energy storage options such as lead-acid batteries to ensure adequate backup for the continuation of power sensitive loads during an extended outage or disruption. This is best reflected in the rapidly changing meaning of the word “reliability”.

Historically, a reliability rate of 99.9%, an average of 8.76 hours of downtime a year, has been acceptable for the power industry. With the increase in the use of computerized systems for various industries, downtime of systems is costly and the reliability factor has become an important issue. In the IT realm, the benchmark in recent years has been “five-nines” (99.999%) or 5.25 minutes per year of downtime, and more recently “six nines” or 31.5 seconds of annual downtime. Now, however, the bar for reliability has been raised to the level of perfection-terms such as “100% reliability”, “zero downtime” are increasingly used to describe the necessary levels of power reliability to support sensitive loads for mission-critical applications.

Section 2.0 Objective of Research

The purpose of the research was to demonstrate the economic and environmental value to stakeholders of deploying condition based maintenance of lead acid battery installations. Specifically I considered four questions:

- What is the best practice in CBM?
- What are the benefits derived from CBM?
- What are the incentives for using CBM?
- What are the environmental benefits of using CBM?

Section 3.0 Materials and Methods

Research was comprised of three approaches:

- **First**, a thorough industry review of traditional practices for maintaining critical power assets, including lead acid batteries, was conducted.
- **Secondly,** a detailed review of leading edge condition monitoring and intelligent analysis of potential battery risks was conducted.
- **Finally**, a detailed review of the best practices for economic and environmental value benefits was performed and results analyzed.

Section 4.0 Condition Monitoring (CM)

The need for adequate predictive monitoring and intelligent analysis of potential risks is both a pressing concern and a requirement for attaining high levels of reliability in any (mission critical) system whose failure will result in the failure of business operations. The trend is and has been toward strategically placed data collection devices on individual components critical to ongoing business activities. The ideal solution provides proactive diagnosis and recommendations for specific actions to prevent unforeseen interruptions from affecting business operations.

Maintenance vendors are shifting their organizations and offerings to provide the best solutions for their customers. The maintenance service industry is in a state of transition as customers shift from traditional break fix services to predictive monitoring and analysis.

The need for adequate predictive monitoring and intelligent analysis of potential risks is both a requirement for the success of the integrated monitoring system and a pressing environmental concern. Traditional maintenance practices rely heavily on services conducted on-site. When battery maintenance technicians are dispatched and travel to a site by truck, plane, or any other means of conveyance they contribute to greenhouse gas emissions, deplete natural resources and damage ecosystems.

Section 5.0 Traditional Maintenance Practices

Section 5.1 Corrective Maintenance

Corrective maintenance is the process of addressing equipment breakdowns after they have occurred. High reliability requires critical power equipment to be repaired rapidly. Over the past several years businesses have become more dependent on their expanding IT infrastructures (the hardware used to interconnect computers and users) to help them automate, manage, and analyze their business strategy. The success of businesses is linked to the continuous availability of IT services which provide reliable data to support the firm's capability to design products and services for their customers. Power breakdowns often equate to IT system downtime which has significant impact on the profitability of a business and is often expressed as dollars lost per minute. The cost due to business interruption can go well beyond the cost of the repair. For example, in banking the average hourly downtime cost is $996K (Iron Mountain 2006)

Section 5.2 Preventative Maintenance

Preventative maintenance (PM) is a proactive service process that seeks to prevent the unplanned breakdown of equipment. Equipment is routinely inspected and serviced at predetermined intervals. PM inspection reports include recorded data that can be manually compared over time to determine if an equipment problem is imminent.

While preventive maintenance is generally considered to be valuable towards avoiding unplanned downtime, there are risks; human error or wear and tear may cause unexpected downtime. Typically original equipment manufacturers (OEM) requirements or regulatory code requirements such as fire codes will dictate when it is proper to perform equipment maintenance and at what interval. The net result of this is that most of the maintenance performed on equipment is unnecessary and may contribute to downtime due to a mistake made by a person.

Section 6.0 Condition Based Maintenance (CBM)

CBM is beginning to change the age-old firefighting mentality of traditional on-site maintenance and replacing it with a more planned maintenance environment. CBM is an idea whose time has come.

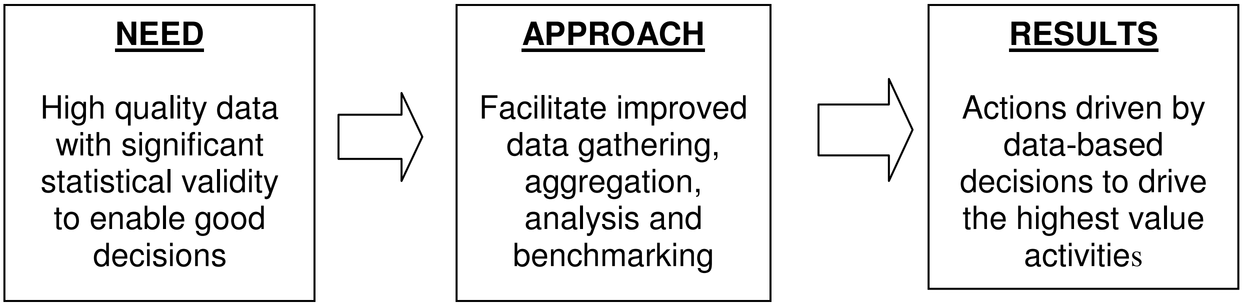
A CBM system will determine the equipment's health and only act when it is determined that maintenance is actually necessary. Developments in recent years have allowed extensive instrumentation of equipment, and together with better software tools for analyzing condition data, the maintenance personnel of today are more than ever able to decide the right time to perform maintenance on a piece of equipment.

Ideally CBM will allow the maintenance personnel to do only the right things, minimizing spare parts cost, system downtime and the premature replacement of assets such as lead acid batteries.

Section 6.1 Major Elements in Data Sharing

CBM operating systems must be designed with three major elements in data sharing. First, there is a need for high quality data typically derived from the appropriate use of embedded diagnostics and prognostics. Secondly, the approach must include automating and trending the results and thirdly, the resultant shared information must have the ability to be used to drive the highest value maintenance activities. Figure 1, below, describes the major aspects of this process.

Figure 1: Major Elements in CBM Data Sharing

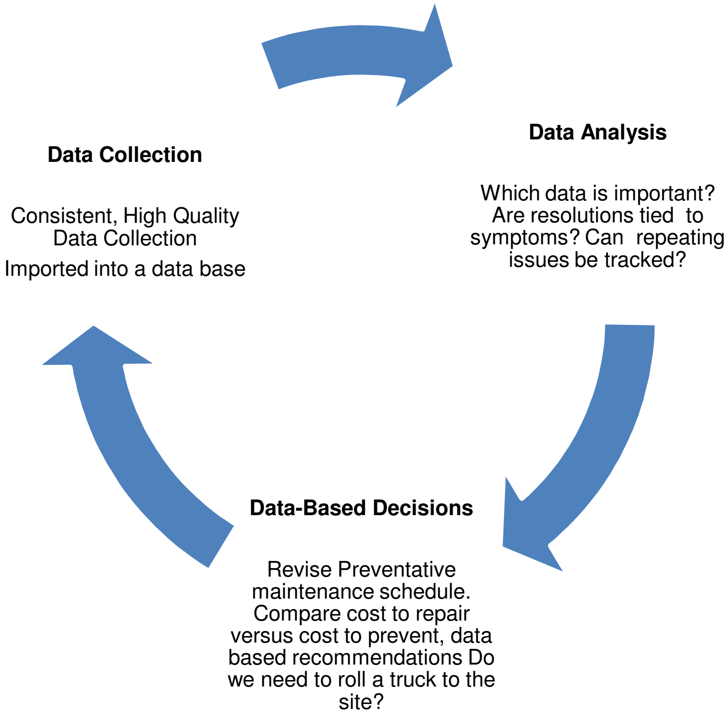


Source: McKenney, Bridget Sandia National Labs, Windpower Monthly Conference- Houston, 23 March 2010

Section 6.2 Getting information from Data

In CBM data is continually being transformed to discover and eliminate the main cause of problems in small incremental steps. This continuous improvement process includes data collection, data analysis and data-based decisions in a continuous loop. This process is depicted in Figure 2 below:

Figure 2 CBM Continuous Improvement Process



Data Collection

Consistent, High Quality Data Collection

Imported into a data base

Data Analysis

Which data is important? Are resolutions tied to symptoms? Can repeating issues be tracked?

Data-Based Decisions

Revise Preventative maintenance schedule. Compare cost to repair versus cost to prevent, data based recommendations Do we need to roll a truck to the site?

Source: McKenney, Bridget Sandia National Labs, Windpower Monthly Conference- Houston, 23 March 2010

Section 7.0 Lead Acid Batteries

The amount of lead used each year around the world is over 8 million metric tons and growing.(U.S. Geological Survey, January 2010) The largest use of lead by far is in the lead acid battery which accounts for 80% of all lead used each year. Keeping the world in motion wouldn't be possible without the lead found in batteries. Renewable energy technologies such as solar cell and wind turbines use lead acid for energy storage and load leveling. Lead acid batteries are key for backing up critical power applications in hospitals, telecommunications, mobile phone networks and emergency services.

Section 7.1 Environmental Health and Safety

Lead-acid battery manufacturers have long known that the handling and use of lead and lead containing products can have adverse health impacts if exposures leading to ingestion and inhalation of lead are not controlled. Scientific studies show that long-term exposure to even tiny amounts of lead can cause brain and kidney damage, hearing impairment, and learning disabilities in children. Lead can be found in the environment from many sources (U.S. Department of Health and Human Services, August 2007):

- Fuel combustion, industrial processes, and solid waste combustion.
- Lead can make its way to water and soils through corroded lead pipes in public and private water systems as well as through corrosion of leaded paints.

- Lead accumulates in the bodies of water and soil organisms. Health effects on shellfish can take place even when only very small concentrations of lead are present.
- Body functions of phytoplankton can be disturbed when lead interferes. Phytoplankton is an important source of oxygen production in seas and many larger sea-animals eat it.
- Soil functions are disturbed by lead intervention, especially near highways and farmlands, where extreme concentrations may be present.
- Lead is a particularly dangerous chemical, as it can accumulate in individual organisms, but also in entire food chains.
- Lead from the 10% of lead-acid batteries that are not recycled.

Nearly 90 percent of all lead-acid batteries consumed in the U.S. are recycled. (U.S. Environmental Protection Agency- n.d.) Lead smelters crush batteries into nickel-sized pieces and separate the plastic components. The smelter then delivers purified lead to the battery manufacturers after the smelting process. A typical lead-acid battery contains 60 to 80 percent recycled lead and plastic.

While the lead-acid battery recycling program is a success by some standards, the reality is that the more it is mined, smelted, and manufactured the more it will be present in our environment.

Primary lead production produces air emissions, process wastes and solid wastes (U.S. Department of Transportation n.d.)

- Air emissions consist primarily of sulfur oxides and particulates.

- Sintering plant air emissions include sulfur and particulates. These emissions are usually burned in the blast furnace and eliminated.
- Particulate emissions from blast furnaces include lead oxides, quartz, limestone, iron pyrites, iron-limestone-silicate slag, arsenic and other metallic compounds.
- Emissions control equipment, usually a baghouse, (an industrial shaft filter often containing hundreds of polyester membrane filters) is most often used to control particulates. (U.S. Environmental Protection Agency 1995)

Liquid wastes from primary lead production include wastewater and slurries. Acid plant blowout from sulfuric acid production plants, slag granulation water from slag disposal, and plant wash down water from housekeeping are the primary types of liquid wastes. The water is considered a hazardous waste RCRA K065 under the Resource Conservation and Recovery Act (RCRA), which by definition "may cause, or significantly contribute to, an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness or pose a substantial present or potential hazard to human health and the environment when improperly treated, stored, transported, or disposed of, or otherwise managed." (U.S. Department of Transportation n.d.)

These tightly regulated wastes must be properly handled not only because of the hazards to employees at the smelter, but also the secondary hazard to human health and the environment once the wastewater leaves the smelting operation. Lead can enter public and private water systems and into bodies of water and soil organisms and eventually into our food chain. (U.S. Department of Health & Human Services, August 2007)

Section 7.2 CBM Role in Maintaining Lead Acid Batteries

Controlling lead acid hazardous waste by-products is at best difficult at a time that lead-acid batteries are being called upon to provide the energy storage and backup power for critical electric power applications. China alone has over 1,500 lead acid battery producers and the market is growing at 20%. (AccessMyLibrary 2009) The best solution is to efficiently manage the use of lead-acid batteries by utilizing 100% of their capacity before replacing them. CBM makes this possible.

Not so long ago the main reason companies monitored equipment condition was to reduce direct maintenance expenses. Condition Monitoring and its logical extension, CBM helped lower life cycle maintenance costs by identifying impending failures early enough to avoid costly repairs and reducing downtime by only performing maintenance when required. It may have taken some convincing in the maintenance department, to change from fighting fires to spotting them, but over time the advantage of identifying little problems before they become big ones proved itself financially through lower repair costs and fewer outages. Aerospace industry reports repair cost reductions of 25-30% after CBM implementation. (Aerospace Industries Association 2007)

Despite the usefulness of CBM the high initial cost of implementation must be considered. Whether it makes sense to invest in technology that provides these features usually depends on scale, location and risk. Where it may not make sense to automate collection and manipulation of a single data point in a local plant, it might make sense to automate it for several hundred sites in a remote location. The cost and availability of people to manually gather and assess data has to be compared with the cost of automating that process, along with the inherent risk of manual error or omission. For example, an error while taking a voltage reading on a battery string may cause the uninterruptible power supply to drop the load and shut down the supported load resulting in costly downtime.

The next three sections (8, 9 & 10) will review CBM use in the maintenance of lead acid batteries, CBM in electrical power substations and consider the economic and environmental benefits of CDM.

Section 8.0 Review of CBM of Lead Acid Batteries

There is a compelling economic and environmental value to both the public utility and their customers in deploying CBM of lead acid batteries. This study will provide an example of best practice CBM and assess its economic and environmental benefits.

Until such time as lead acid batteries are required they are kept in a state of full charge to ensure the maximum run time when called upon. In many cases lead acid batteries can fail within just a few days.

Section 8.1 Battery Condition Monitoring (Hanking, 2008)

1. Provide an accurate battery condition report with continuous, accurate monitoring and alarm notification.
2. Provide clear information in the form of graphs for forensic analysis.
3. Allow extended life of the batteries through efficient and rapid preventative maintenance.

Managing the batteries of an electrical substation with a modern battery monitoring system provides a number of benefits. A system that provides daily value readings can:

1. Greatly reduce the risk of unplanned downtime due to battery failure.
2. Reduce the workload for the maintenance team, increase battery and workforce efficiency and provide the proper management of very large numbers of batteries.

3. Provide immediate notification of detected faults.

4. Ensure that future battery replacement is carried out in a properly timed and budgeted manner.

5. Improve environmental, health and safety conditions for personnel tasked with battery maintenance.

Section 8.2 The Risk of Not Having Battery Monitoring

Any critical power back up system that does not take into consideration the condition of its batteries risks failure of the entire system. Substation batteries represent a strategic investment for utilities. These batteries are typically drawn upon to provide backup power to switching components and to power the substation.

Condition Monitoring and CBM have been around long enough to be understood. Progressive organizations adopted these techniques and justified them through savings on direct maintenance costs. (The Aerospace Industries Association, May 2007) Condition monitoring frees people’s time that otherwise would be used for on-site service, to do the things that are most important: planned and predictive tasks. Implementing CM was usually straightforward since most plants already collect significant amounts of operating data, and it required only the addition of a management plan and a way to aggregate information in a usable form to create the CM program.

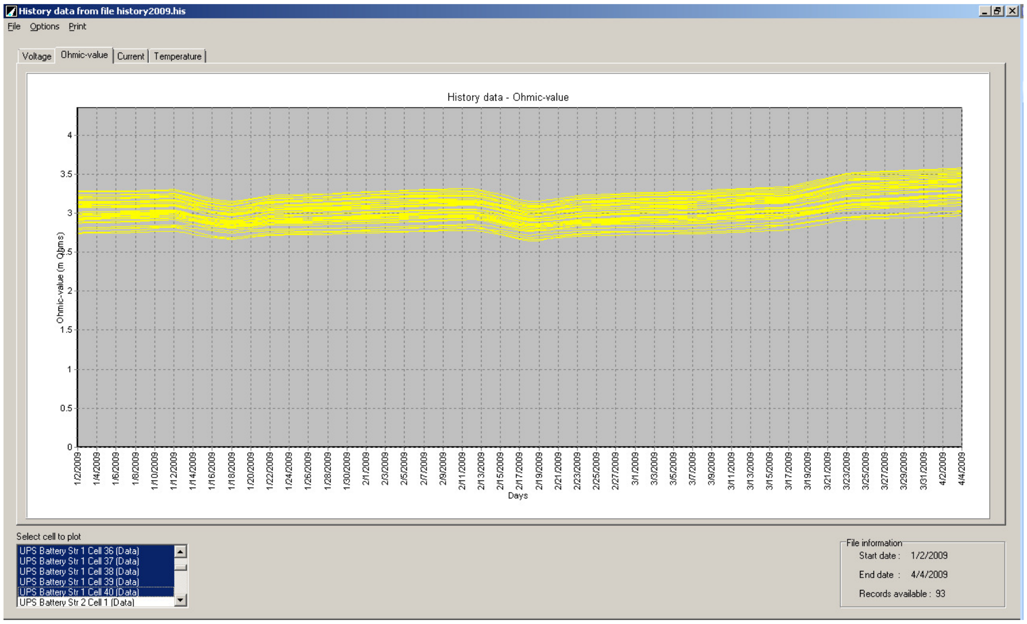
Today, critical labor shortages in trades and technical roles have increased downtime risk to such a level that there is a new urgency to leverage CM to increase labor productivity and avoid lost production. The combined effect of retiring baby-boomers and a reduced interest in technical education and trades has left industry short of qualified people (Currie, 2006) to operate and maintain facility infrastructures. Condition Monitoring is no longer considered just an engineering tactic; it is valuable management strategy for coping with changing economic circumstances. As Condition Monitoring receives greater emphasis in the business planning cycle, so too will technologies that enable it. As with all technology investments, those made with a clear purpose in support of coherent management programs will provide the best results.

Section 8.3 Batteries Through the Eyes of a Battery Monitoring System

The core of a battery monitoring system is to identify conditions leading to equipment failure, avoiding them in the future, and extending the life of the batteries-in other words, working more productively over the life of a battery.

In this section the condition of the battery string will be examined through the eyes of a battery monitoring system. The screen shot is from an actual battery installation (See graph 1 below) and will provide insight into all electrical parameters as well as the ambient conditions of the installation. These screen shots, such as the one provided below obtained from the NDSL Group Ltd. website www.cellwatch.com will indicate the health of the batteries and their ability to carry their rated load should it become necessary. Screen shots typically provide real-time battery performance review and can be accessed from a personal computer on the network or on the web.

Graph 1: Sample Battery Monitoring Screen Shot



UPS Battery Str 1 Cell 36 (Data)
UPS Battery Str 1 Cell 37 (Data)
UPS Battery Str 1 Cell 38 (Data)
UPS Battery Str 1 Cell 39 (Data)
UPS Battery Str 1 Cell 40 (Data)
UPS Battery Str 2 Cell 1 (Data)

Start date : 1/2/2009
End date : 4/4/2009
Records available : 93

Monitoring data is typically presented in a user friendly format with extensive data trending. In CBM this battery data is continually being transformed. The continuous improvement process includes data collection, data analysis and data-based decisions in a continuous loop. This continuous loop was described in Diagram 1.

Section 9.0 Analysis: Electrical Power Substations

Substation batteries represent a strategic investment for utilities. These batteries are typically drawn upon to provide backup power to switching components and to power the substation control equipment in times of AC power loss. An increased emphasis of the power industry on systematic asset management, enhanced reliability, and infrastructure security are motivating power utility engineers to look at substation batteries and the potential for lost production and extended downtime. Batteries are the major component of more than 100,000 such systems in the United States. An Electric Power Research Institute (EPRI) survey of 100,000 electrical substations in the US was conducted to baseline current lead acid battery maintenance practices in substations.

The results of the EPRI survey identified opportunities for improved battery maintenance while reducing the need for on-site maintenance. This analysis will look at the environmental benefits derived from this switch from traditional maintenance practices to CBM.

Section 9.1 Electrical Power Research Institute Survey of Power Substations

Electrical substations come in a variety of types; transmission substations, distribution substations, switching substations, etc. Batteries in a substation are used to power switchgear in the event of a power failure. Roughly 83% of all substations have batteries for back-up power. Table 1 below shows that the frequency of on-site preventative maintenance of batteries varies greatly, from less than once a month to annually. Most of the substation sites maintained their batteries quarterly and 60% of the batteries lasted for 5-10 years, 20% less than 5 years and 20% over 5 years. This data will be useful as we analyze the economic and environmental impact of CBM.

Table 1: Compiled Results of EPRI Survey

Compiled Results of EPRI Survey	
Electrical Substations in the U.S.	**100,000**
Electrical Substations employing lead-acid batteries	**83,000**
Preventative Maintenance Frequency	
➢ Monthly	**2,075**
Monthly	**31,125**
Quarterly	**37,350**
Semi-Annual	**10,375**
Annual	**2,075**
Reported Battery Life	
< 5 years	**15,936**
5-10 years	**51,128**
>10 years	**15,936**

Source: (EPRI 2003)

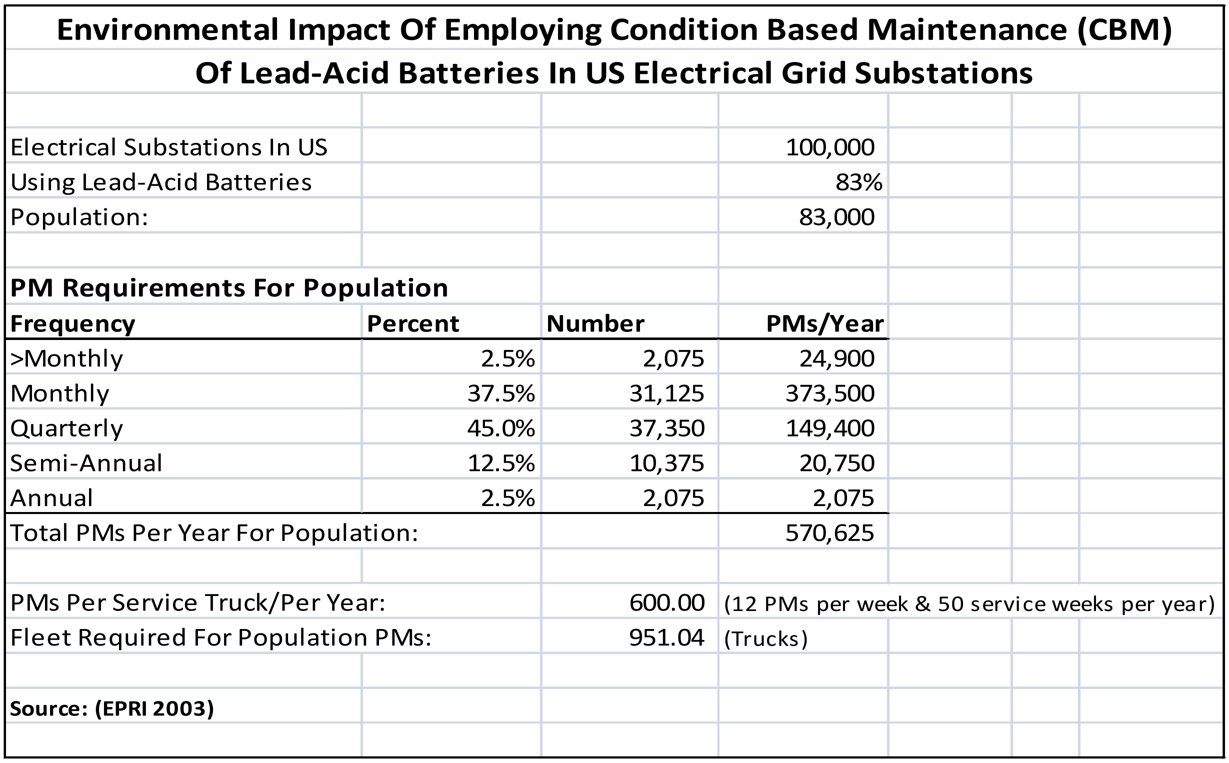
Section 10.0 Environmental Responsibility

The EPRI study concluded that there are 83,000 electrical substations in the US that use lead acid batteries as backup power. As traditional maintenance practices get more costly and instrumentation and software systems get less expensive, CBM becomes an important tool that reduces maintenance costs and lowers use of natural resources. What follows is an environmental benefit analysis of CBM at these electrical substations.

Section 10.1 Pre-CBM Considerations

Today, U.S. electrical substations are largely using traditional maintenance practices to maintain their lead acid batteries. EPRI substation survey data (compiled in Table 1) suggests in Table 2 below that given the mix of preventative maintenance visits, over 570,000 visits are conducted annually to support 83,000 substations; this effort requires a fleet of 951 trucks on the road driving between the nation’s over 83,000 electrical substations.

Table 2: Preventative maintenance resources deployed prior to CBM

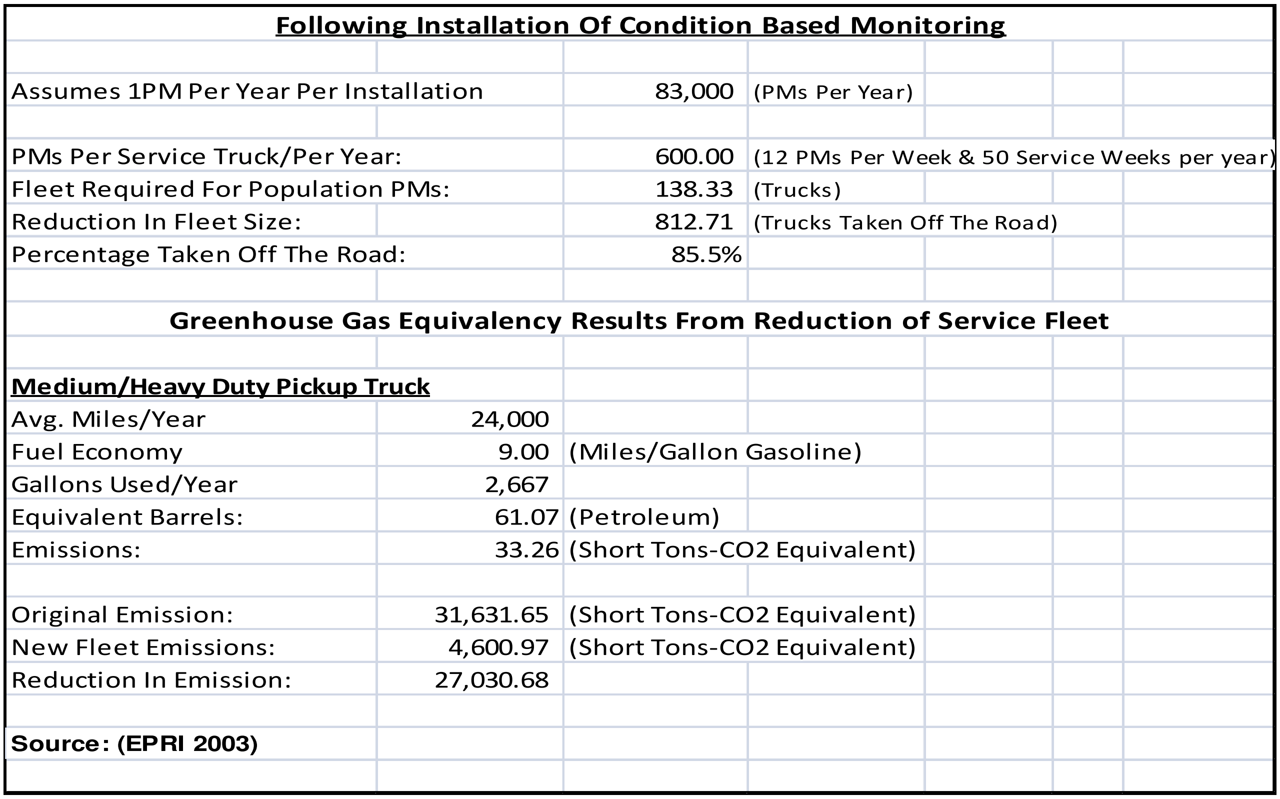


Environmental Impact Of Employing Condition Based Maintenance (CBM) Of Lead-Acid Batteries In US Electrical Grid Substations			
Electrical Substations In US			100,000
Using Lead-Acid Batteries			83%
Population:			83,000
PM Requirements For Population			
Frequency	**Percent**	**Number**	**PMs/Year**
>Monthly	2.5%	2,075	24,900
Monthly	37.5%	31,125	373,500
Quarterly	45.0%	37,350	149,400
Semi-Annual	12.5%	10,375	20,750
Annual	2.5%	2,075	2,075
Total PMs Per Year For Population:			570,625
PMs Per Service Truck/Per Year:		600.00	(12 PMs per week & 50 service weeks per year)
Fleet Required For Population PMs:		951.04	(Trucks)
Source: (EPRI 2003)			

Section 10.2 Post CBM Improvements

Table 3 below shows the impact of CBM on the number of preventative maintenance visits required per year. With CBM in place, each site would be visited annually for a total of 83,000 visits. This represents an 85% reduction over the 570,625 preventative maintenance visits required before CBM implementation. There would be a proportional reduction in the number of trucks required, which results in over 800 trucks removed from the nation’s roads. This represents a reduction of over 27,000 short tons of CO2 equivalents annually (U.S. EPA CO2 calculator). This was calculated at 33.26 short tons-CO2 equivalent per truck taken off the road or just over 27,000 short tons total for the fleet reduction of 812 trucks.

Table 3: Preventative maintenance resources deployed after CBM

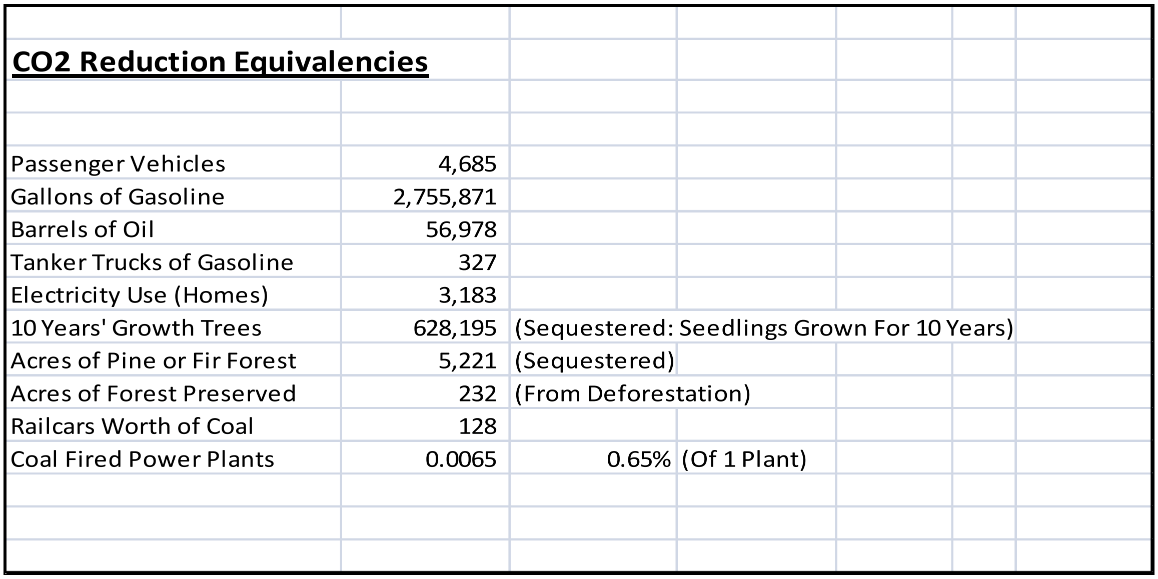


Following Installation Of Condition Based Monitoring			
Assumes 1PM Per Year Per Installation		83,000	(PMs Per Year)
PMs Per Service Truck/Per Year:		600.00	(12 PMs Per Week & 50 Service Weeks per year)
Fleet Required For Population PMs:		138.33	(Trucks)
Reduction In Fleet Size:		812.71	(Trucks Taken Off The Road)
Percentage Taken Off The Road:		85.5%	
Greenhouse Gas Equivalency Results From Reduction of Service Fleet			
Medium/Heavy Duty Pickup Truck			
Avg. Miles/Year	24,000		
Fuel Economy	9.00	(Miles/Gallon Gasoline)	
Gallons Used/Year	2,667		
Equivalent Barrels:	61.07	(Petroleum)	
Emissions:	33.26	(Short Tons-CO2 Equivalent)	
Original Emission:	31,631.65	(Short Tons-CO2 Equivalent)	
New Fleet Emissions:	4,600.97	(Short Tons-CO2 Equivalent)	
Reduction In Emission:	27,030.68		
Source: (EPRI 2003)			

Emission calculators are useful to approximate the tons of carbon dioxide generated from activities and how many trees it would take to offset those emissions. (EPA n.d.)

Table 4 below provides insight into many of the more common CO2 reduction equivalencies. These CO2 reduction equivalencies provide a compelling argument for the implementation of CBM.

Table 4: CO2 Reduction Equivalencies



CO2 Reduction Equivalencies

Passenger Vehicles	4,685		
Gallons of Gasoline	2,755,871		
Barrels of Oil	56,978		
Tanker Trucks of Gasoline	327		
Electricity Use (Homes)	3,183		
10 Years' Growth Trees	628,195	(Sequestered: Seedlings Grown For 10 Years)	
Acres of Pine or Fir Forest	5,221	(Sequestered)	
Acres of Forest Preserved	232	(From Deforestation)	
Railcars Worth of Coal	128		
Coal Fired Power Plants	0.0065	0.65%	(Of 1 Plant)

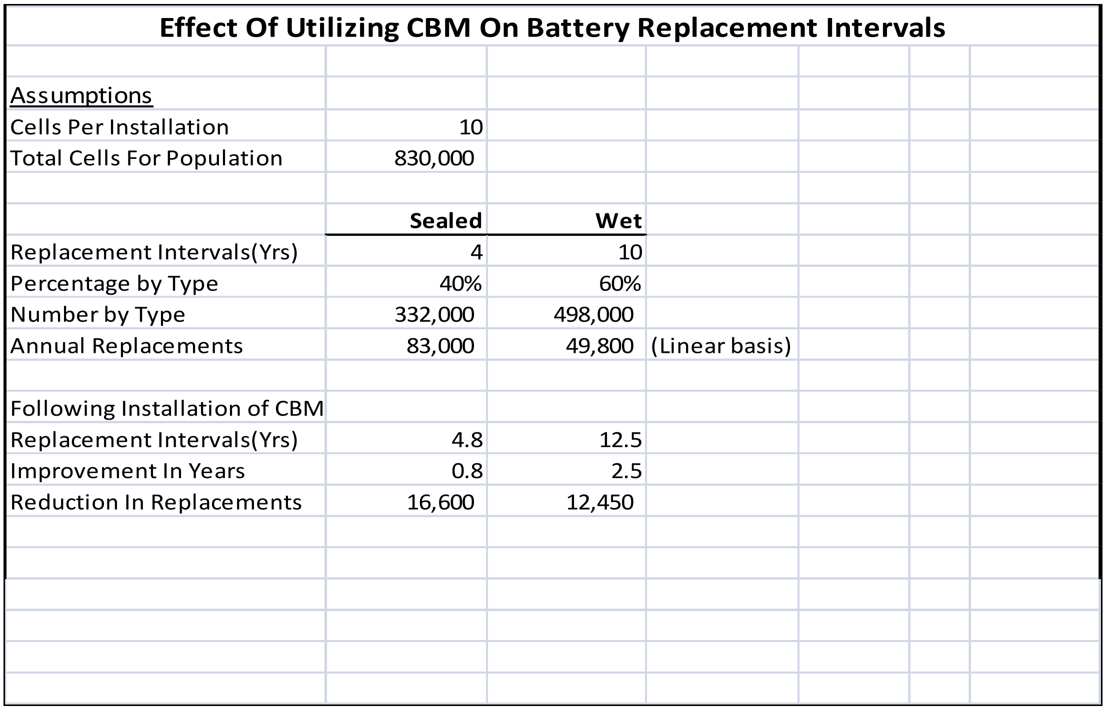
CBM optimizes the way sub-station batteries are maintained which leads to lower use of natural resources, namely lead. CBM will give visibility to how much battery capacity remains just as a fuel gauge on a car will provide ample warning of low fuel. This is accomplished by taking hourly voltage readings, daily resistance readings and continuous current readings from each cell of the battery and then interpreting and displaying the results. This visibility allows for battery life optimization and results in a significant increase in battery life. Should a single battery in a string of batteries fail the failed battery is replaced before the battery string degrades.

Table 5 below shows the effect CBM has on battery replacement intervals. Pre-CBM the total number of battery replacements totaled 83,000 for sealed lead acid batteries and 49,800 for wet-cell lead acid batteries for a total of 132,800 batteries replaced annually.

Post-CBM implementation the life of the battery increased by 20% for sealed lead acid batteries and 25% for wet-cell lead acid batteries. This resulted in 29,050 fewer batteries replaced annually.

The educated assumption here is that the batteries can be utilized more completely and pro-active replacements are no longer necessary.

Table 5: Effect of Utilizing CBM on Battery Replacement Intervals



Effect Of Utilizing CBM On Battery Replacement Intervals

Assumptions			
Cells Per Installation	10		
Total Cells For Population	830,000		
	Sealed	**Wet**	
Replacement Intervals(Yrs)	4	10	
Percentage by Type	40%	60%	
Number by Type	332,000	498,000	
Annual Replacements	83,000	49,800	(Linear basis)
Following Installation of CBM			
Replacement Intervals(Yrs)	4.8	12.5	
Improvement In Years	0.8	2.5	
Reduction In Replacements	16,600	12,450	

Section 11.0 Conclusion

CBM is a maintenance tool that has not been widely implemented. As this paper demonstrated with batteries in substations there is much to be gained in asset reliability and reduced maintenance costs at a time when employing highly efficient energy strategies is necessary to achieve our nations goal of stabilizing greenhouse gas emissions and meeting our energy needs.

CBM is an example of practical energy use through avoided traditional maintenance practices using proven technologies that are commercially available. This technology can be scaled up to make significant impacts on greenhouse gas emissions.

In today’s economic climate the initial cost of CBM is high. The improved instrumentation of the equipment can be costly especially in retrofits. In addition CBM is a big change from traditional maintenance practices that will require change within the entire service organization. Further cost reductions will be necessary for wide-spread implementation.

As the economy improves CBM will grow in popularity wherever outdated infrastructures are proving themselves unreliable for sensitive operations. CBM will drive reliability higher and result in the more efficient use of lead acid batteries with the added benefit of reduced CO2 emissions.

Section 12.0 Future Considerations

Additional insights into the value of CBM as a strategic maintenance tool that improves reliability and reduces CO2 emissions could be obtained by an in-depth qualitative approach that may include field visits and interviews to understand why the decision was made to use or not to use CBM in other industries, i.e. telecommunications, wind energy, mass transit to determine the success of CBM.

As the digital economy demands improvements in the quality of power and the energy storage market continues to grow CBM will dominate the maintenance scene in the coming decades.

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