Automated and cost effective maintenance tools

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Abstract

Continuous real-time monitoring of batteries has been advocated for improved reliability of standby power plant. However, existing commercial monitoring systems often fail to meet user expectations and are therefore difficult to justify for wide-scale implementation. A model which accommodates user-based ideas about the functions of battery and power system monitoring is described. The development of a low cost, "universal" battery and power monitoring system suitable for implementation across Telstra's network is also reported.

Introduction

Battery integrity is critical to the standby power function. Real-time continuous monitoring is now generally considered to be part of the pathway to improved battery system reliability, particularly for installations using valve-regulated lead-acid (VRLA) battery technology [1-3]. Integration of new techniques such as cell and battery impedance or conductance measurements has been advocated to both increase the efficacy of on-line monitoring systems [3], and to eliminate many of the problems associated with manual impedance measurement of on-line standby batteries [4].

The case for continuous, on-line battery monitoring in UPS applications has been made [1,2]. Different engineering methods have been reported [5-8] and a number of systems are now available. Commercially available battery monitoring systems typically involve *broad-based surveillance* of a relatively large number of batteries by centralised logging equipment. These systems are characteristically expensive and often require a secondary level or platform of support for the storage, processing and interpretation of collected data.

The case is no less valid for some sort of monitoring system in the telecommunications sector where the trend towards decentralised battery-backed power systems and new cost pressures threaten traditional operating and maintenance practices. Indeed, the future "hands-off" remotely controlled, operated and maintained telecommunications network implies some degree of power and battery system monitoring will be necessary. However, studies by the Telstra Research Laboratories have found that in general, end-user expectations of battery monitoring equipment are rarely achieved, and most systems demand a support platform which is often outside the existing circumstances of the end-user. The value-added aspects of existing commercial battery and power monitoring systems are not proven for telecommunications applications, and thus may not be cost effective for wide-scale implementation across the network. This apparent lack of useful functionality needs to be addressed.

This paper examines user-based rationale for the functionality of a battery or power monitoring system in a telecommunications environment from an operational and maintenance point of view, and describes the development of a low-cost, universal battery and power monitoring system suitable for implementation across the network.

A *User-based* Functionality Model.

The determination and inspection of user requirements as a pathway to improved battery monitoring systems has recently received consideration [9,10]. One way to establish *user-based functionality* for a battery monitoring system is to use existing plant and operating infrastructure as the starting boundary condition.

Telstra operates a geographically diverse network across Australia which includes a historical mix of centralised power systems, solar-power systems, newer distributed power architectures and smaller kerb-side power supplies. There is therefore considerable diversity in both power equipment and lead-acid battery technologies in the network which must be subjected to life-cycle support strategies. Given this diversity, standardised and universal operational procedures are important unit cost factors. Battery and power monitoring systems have merit only if there is a clear cost benefit to the overall operational maintenance effort within the context of existing network infrastructure.

It is possible to define various "acceptance criteria" which must be met before the introduction of battery monitoring systems into the network. A summary is given in *Table 1*. Cost is an obvious parameter, particularly if it is linked with retrospective installation and an "universal" device. A parallel add-on type of device allows retrospective fitting, and there is advantage in adopting a single, "universal" device for all types of battery installations. Telstra does not have any uniform centralised data collection infrastructure for power systems. Local, stand-alone systems are therefore of more immediate practical benefit. However, extrapolating from trends in other areas of network and operational management, remote, hands-off battery and power system management may well be a future mode of operation. But it is critical that adoption of battery or power monitoring systems in the first instance does not require the simultaneous implementation of centralised surveillance.

Consideration	Aspects
Task based Obligatory	• Improved maintenance productivity • Automation of current record-keeping practices • Alarm Exception conditions • Function as on-site trouble-shooting tool
Preferable	• Capture unattended information • Provide protected battery history • Trend analysis
Realities	• Very low cost for device • Reduce existing maintenance costs • Standardised approach
Influences	• Universal application with single device type • Stand-alone device with future net-working capabilities • Retrofitable to diverse range of equipment

Table 1: Some "acceptance criteria" for introduction of battery and power monitoring systems in Telstra.

Event Recording Concept

The major influence in battery monitoring equipment functionality comes from considering the productivity of maintenance effort. The advantage of continuous monitoring to trap unattended events is obvious. The ability to track system performance during normal line failures is useful and may avoid the inconvenience and risks associated from routine test discharging.

However, the potential of monitors to guide corrective or proactive maintenance action is less evident. For instance, in Telstra's remote solar powered network, a low volts alarm results in the dispatch of urgent maintenance action to recharge the batteries. The cause of the low battery capacity may not be evident, and this often results in costly, repeated call-outs. The reactive maintenance may be made more effective if the recent history of the power system performance parameters were at hand to help identify the cause of the under-charged condition.

Similarly, recent histories of battery *and* power system behaviour after planned or unplanned outages would help correctly target maintenance effort. That is, for Telstra, battery monitoring equipment would be more functionally attractive if there were local "intelligent" event recording facilities.

The targeted user-based functionality design is therefore based on a localised Event Recorder concept. Integration of this concept with the wider "acceptance criteria" of Table 1 results in the development of a universal battery monitoring task model. The model takes a different perspective and approach to surveillance of physical data to that normally associated with commercial battery or power monitoring systems.

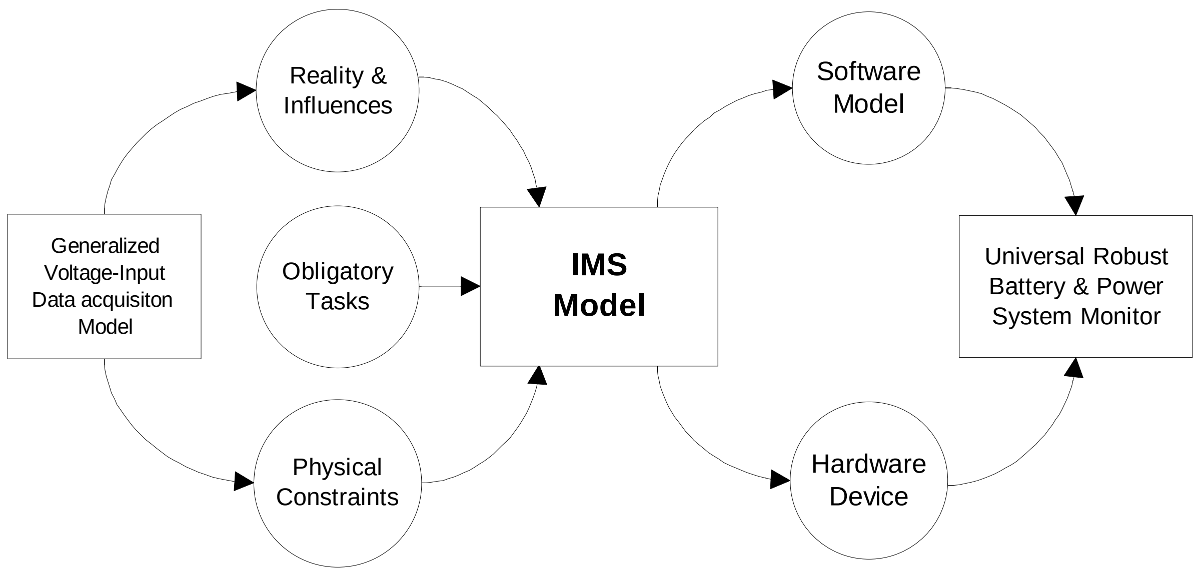

Figure 1 : Pathways used in developing the IMS model

The task model, known as the Intelligent Monitoring System, or IMS, is characterised by an "intelligent" balance between the data collection and storage activities *(logging)* and the system condition assessment tasks *(monitoring)*. Each of the tasks can be allied with particular existing maintenance actions (or lack thereof). This concept lends itself well to power system monitors, not just battery monitors. Further, the *model* is independent of either the centralised or local status of the battery data collection activities associated with commercial battery monitoring systems. *Figure 1* illustrates the generalised linkages and pathways used to develop this universal battery monitoring task model. From this model a low cost, practical and realised "universal" IMS device has been developed.

As indicated in *Figure 1*, the IMS Model results in very decoupled software and hardware. That is, the tasking software is functionality objective, and could easily execute on other hardware. This is an important outcome because many commercial battery monitoring systems lose some functionality because of inflexible coupling of operating software with the physical hardware. The hardware device developed in this work is a compromise solution given the competing influences and realities listed in *Table 1*.

Parameter Selection

In the attempt to achieve a low cost, "universal" battery and power monitoring system, the measured parameter set must be considered. The dilemma of what, how and why to measure in a battery monitoring system typically skews hardware design and selection. However, some gains can be made by firstly recognising that, for standby service, there is no genuine battery fuel gauge, and secondly, most of the conventional physical parameter measurements are historical in origin. From a pragmatic point of view, recently reported techniques indicate that better methods to determine critical battery "state-of-health" criteria can reasonably be expected in the future [1,3,9]. It therefore follows that a newly developed battery monitoring system should preferably exhibit flexibility to accommodate changes to both the collection and utilisation of the parameter set.

The IMS Model is based on a generalised voltage input data acquisition design and does not limit the type of input parameter. There are, of course, limits placed on both the dynamic range of the voltage presented to the analogue input multiplexer hardware, and the physical number of analogue input channels available, but these limits need not affect the actual software tasking functionality. In Telstra, the majority of battery banks in the network are based on the traditional 24x2V cell configuration, and this is the driving criterion for dynamic range and number of input channel limitations. Situations requiring more input channels, say for UPS applications or for multiple parallel battery banks, are addressed by using more than one IMS. The major cost of any battery monitoring system is in the analogue input acquisition circuitry, not in the support digital electronics. It is thus more cost effective to utilise multiple devices operating the same software than it is to have multiple input structures (to accommodate different battery installations) with associated variations in software.

Local Event Recording

The attractiveness of the IMS is in the local event recording mode of the software. *Figure 2* illustrates the different types of event recording classes implemented with the IMS model. In practical terms, the Trend Tracker and Battery History classes relate to continous logging activities, while the Discharge Logger and Exception Register relate more to random and unpredictable real-time events.

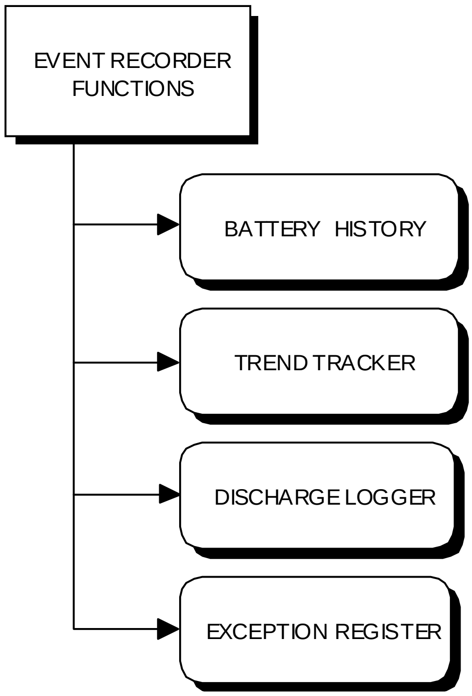

Figure 2: Event recording elements of the IMS Model.

Each event type can be associated either directly or indirectly with one or more real inputs. As an example, *Figure 3* demonstrates how three different windows of *trend tracking* are achieved within the IMS. Short-term, mid-term and long-term data describing system parameters and any derived information are available at any time. *Table 2* lists typical time dimensions for these trend windows. For example, 8 hours of the most recent time sequential processed data, time-resolved to 5 minutes, is locally available for any and all of the defined inputs associated with the short-term trend. Similarly, the mid-term trend contains the most recent 8 day history, resolved to 1 hour. The long-term

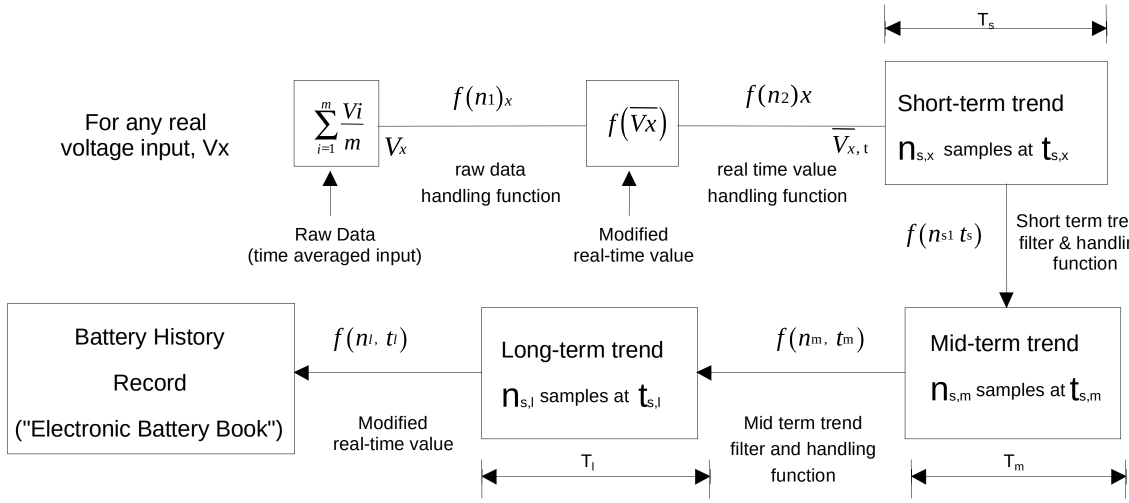

Fig. 3: Implementation of the Trend Tracking class of event recording facilities in the IMS Model. Handling functions and filters, f(x), apply to each input, or derived (virtual) input, V_X, and are programmable. Each trend is characterised by **n** samples taken at **t** time intervals over a total trend period, **T** *(see text).*

trend gives the most recent 30 day trend. Ultimately, the trend data is selectively filtered off into the Battery History register. The Battery History is the automation of the existing prescribed manual battery measurement routines, and as such can be described as the "electronic battery book". The Battery History data is protected, thus creating a local, electronic, permanent record of performance over the service life of the battery.

Trend Tracker	**t** sampling rate	**T** trend window	**n** no of samples
short-term	5 min	8 hr	96
mid-term	1 hr	8 day	196
long-term	24 hr	30 day	30
Battery History	30 day	unlimited	unlimited

Table 2: Typical trend window dimensions

The trend trackers are circular memory designs, and thus only the most recent trend data is locally available. This recognises that storage of 5 min samples for the life of the battery is both unreasonable and unnecessary. From an operational point of view, the more recent history information is most relevant. Connection of the IMS to a remote device provides a means to build an extended set of highly time-resolved data by retrieving data a a more frequent rate.

The surprising outcome of this approach is the relatively low rate of local memory consumption. The IMS can implemented with only 64K of RAM with less than 20% consumption per year of operation for the typical 24 cell battery installation using 30 day history records. Such low memory requirements reduces costs, limits the physical size and enables useful local functionality without the need for centralised data collection.

The IMS Device

The general specifications and features of the Telstra implementation of the IMS model are given in *Table 3*, and some typical input parameters assignments are listed in *Table 4*. The device has a 32 channel voltage input structure arising from modelling the 24x2V cell

Category	Description
Analogue	32 differential channels
input range	± 100V (2000V isolation)
scaling	auto-ranging
ADC	13 bit 100µsec, SAR ADC,
Digital	68HC11 series 8-bit CPU
RAM	32K-128K non-volatile
ROM	128K UVEPROM (secure)
User interface	2-line LCD display & keypad
Remote access	isolated RS-232 (9 pin)
Powering	self-powered by monitored battery
Oper. range	± 8V - ± 100V, fully isolated
Power consumption	approx. 500 mW_{av}
Physical	
Dimensions	104 (W) X 50 (H) x 270 (L) mm
Input loom	universal 68 way mini-centronics

Table 3: Some IMS hardware specifications

structure of the standard 48V battery bank installation. All other types of battery banks in Telstra, except for UPS installations, can be modelled as a subset of the 24 cell situation. UPS installations in Telstra can usually be accommodated by some integer multiple of 24 or 32. The input channels have a high common-mode voltage tolerance and auto-ranging software ensures that there is no functional difference between 2V cells and 6V or 12V monoblocks.

The IMS is self-powered from the battery installation under measurement and has very low power consumption. Collected data is memory protected. A standardised, "universal" input loom is utilised for all battery configurations. Intercell conduction integrity is directly measured by the two wire per cell or monoblock connection scheme. The IMS currently utilises single frequency impedance measurement as a core set of the battery and power system parameter set. All configuration options are software implemented. There are no hardware switches or settings, thus avoiding the need for field adjustment and the possibility of incorrect configuration.

Input Associations
• Battery bank(s) voltage and impedance • Cell or Monoblock voltages and impedances • Interconnection voltages and impedances • String float and load current • System temperatures • Amp-hours passed • Array current input (solar)

Table 4: List of typical system parameters measured and utilised in the IMS

Costs & Future

The IMS meets the original costs target of developing a small, compact "black box" intelligent battery monitoring system for between 5% and 10% of the capital cost of Telstra's typical 24x2V cell, 500 Ah battery bank. For installations using smaller numbers of cell or monoblocks, the unit costs can often be shared across two or more parallel banks.

The capital cost of the IMS becomes significant for the relatively small power supplies used in curb-side cabinets which typically contain less than 80 Ah (C_{10}) of standby battery capacity. However, battery and power system management and the life-cycle support effort is no less important than for the larger, conventional telecommunications DC power plant, particularly with the increase in power supply distribution in Telstra's access network.
Current development efforts are focussing on ways to optimise hardware design specifically for small access network power supplies. The IMS model provides a convenient means to capitalise on the generic Battery Condition Monitor (BCM) function of modern telco power supplies. The BCM typically tests for out-of-limits conditions of the total bus voltage as the rectifiers are disconnected and the batteries totally support the load. The high resolution voltage and impedance measurement capabilities of the IMS can be used to more "intelligently" assess cell and battery condition during the automatic, short time BCM test. The ability of the IMS to operate in stand-alone mode or as part of a remote access strategy makes it an ideal candidate to meet the demands of future modes of operation of network management.

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References

[1] D. Berndt and E. Meissner, "Monitoring of Stationary Value Regulated Lead Acid Batteries, in *Proc. Conf.* INTELEC 91, 1991, pp 181-188.
[2] R. Gruenstern, M. Reher, S. Gerner and D. Shaffer, "Improved system reliability through improved monitoring techniques", in *Prof. Conf.* INTELEC 93, 1993, pp 63-66.
[3] D. Berndt, Maintenance-free Batteries, Research Studies Press, Somerset, 1994, pp 311-317.
[4] J.M. Hawkins, "Some Field experience with battery impedance measurement as a useful maintenance tool", in *Proc. Conf.* INTELEC 94, 1994, pp 263-269.
[5] J. Parsons and P. Sanctuary, " The need for battery monitoring", in *Proc. Conf.* INTELEC 91, 1991, pp 171-176.
[6] Z. Noworolski, "A microcomputer-based battery Management system", in *Prof. Conf.* INTELEC 91, 1991, pp 177-180.
[7] G. Pedersen, "The use of ratiometric measure-ments to determine battery status", in *Proc. Conf.* INTELEC 94, 1994, pp 491-496.
[8] T. Suntio, "Imperfectness as a useful approach in battery Monitoring", in *Prof. Conf.* INTELEC 94, 1994, pp 481-485.
[9] F.J. Suiter and T.M. Cortes, "Considerations for a reliable telecommunications power system at remote facilities utilising valve-regulated lead-acid battery management system technologies", in *Proc. Conf.* INTELEC 94, 1994, pp 464-468.
[10] J. Poulin, R. Heron, and D. Mailloux, "An expert Management System for VRLA batteries in Remote Telecommunications Centers", in *Proc. Conf.* INTELEC 94, 1994, pp 497-504.

