Beyond Prepayment – Smart Meters for Evolving Networks

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1. Introduction

Prepayment meters have become an essential tool for the delivery of electricity services to developing communities. Domestic consumers prefer prepaid services due to the financial control its provides them, and the simple rate of consumption feedback presented. The products have matured, become more dependable and have been internationally standardised. Vending systems have likewise evolved into online transaction servers regulating significant flow of funds.

However, there is growing evidence that the basic prepayment meter is lacking significant attributes important to the provision of a safe, sustainable and satisfactory service to consumers. This paper seeks to shed light on improvements that are emerging and highlights the work that needs to be done to ensure that all manufacturers adopt a common set of enhancements.

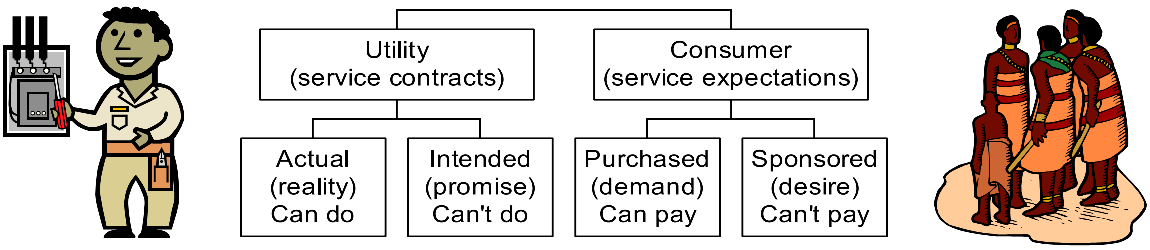
2. Service experiences and the equity challenge

The white paper[1] on transforming public service delivery defines the "Batho Pele" principle of putting people first, which requires;

- redressing the imbalances of South Africa's past
- maintaining continuity of service to all levels of society
- focusing on the needs of the 40% of South Africans who are living below the poverty line
- a shift away from inward-looking, bureaucratic systems, processes and attitudes
- a search for new ways of working which put the needs of the public first, is better, faster and more responsive to the citizens' needs.

The objectives of service delivery enhancement therefore include welfare, equity and efficiency.

Obviously, the rising occurrence of public protest is evidence that consumer experiences are not meeting the rising expectations. Figure 1 presents a simple model to illustrate the service delivery gaps that exist. These are noted in more detail thereafter.



Actual – Intended Gap:	Result of difficulties in service provision and maintenance
Intended – Purchased Gap:	Result of mis-communication and lack of flexibility
Actual – Purchased Gap:	Result of short comings and mis-informed expectations
Actual – Sponsored Gap:	Result of lack of priority, policy, capability and capacity etc

Figure 1: Service perception gap analysis

The intuitive notion that sponsored (indigent) consumers are due an inferior service as they are not paying for their services, has to be challenged. The Batho Pele principle requires that a child headed family in an AIDS plagued community, must be given an equitable level of service. The fact that we aren't sure how to do this in a sustainable manner or that we don't have the capital, generation capacity or capability to do this is a different matter. We cannot deny the challenge.

3. Planning for escalating service expectations

It needs to be appreciated that satisfactory service levels are not static. Thus what was an acceptable service five years ago, is no longer sufficient to fulfil a consumers escalating expectations. This can be demonstrated by observation of the highly competitive computer industry as shown in Table 1. This parallel creates a sub-conscious precedent in a consumers mind as to what service levels could/should be. It is worth contrasting this with the service practices prevalent in the monopolistic electricity industry. Sadly, most of the electricity industries service levels are constrained by the capabilities of equipment installed in the 60's and 70's.

Decade	Label	Ability	Defining Activity
1940's	Showing	Display	Store owner chooses when and where to exhibit
1950's	Telling	Present	Sales force go out and describe extent of services
1960's	Selling	Listen	Marketing staff emphasise benefits of their services
1970's	Choice	**Diversify**	Customer selects what he wants from many options
1980"s	Now	**Deliver**	Customer says when and where he wants it
1990's	"I"	**Customise**	Customer defines the service he wants and gets it
2000's	**Value**	**Value Eng**	**Customer declares what he is prepared to pay**
2010's ?	Saving	**Conserve**	Customer controls and directs his usage
2020's ?	Control	**Manage**	Customer expects service integration benefits
2030's ?	Morph	**Adapt**	Co-generation and adaptive infrastructures

Table 1: Characteristics of service escalation since the 1940's

Perhaps it is unfair to compare the fast moving computer industry where product lifetimes are as short as three years, to the electricity industry that typically has thirty year product lifetimes. But this is exactly the point – the long product lifetimes that presently constrain the service options available to a utility, must force us to consider the service requirements of new meters to at least thirty years into the future. This requires some serious crystal ball gazing and industry consensus building efforts. The capability to achieve this needs to be strengthened and mentored.

4. Waves of service convergence ignite innovation

The prepayment industry came about through the convergence of electronic measurement technologies and low voltage switchgear technologies. It is increasingly apparent that these technologies are now converging with public communication infrastructures, thereby spawning a new generation of "smart electronic meters". Figure 2 illustrates some common forms of these products and lists the related IEC standardisation working group and normative specifications.

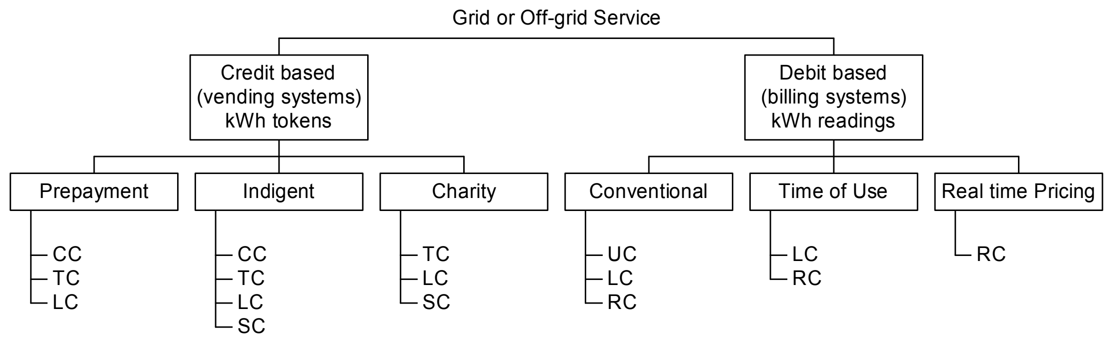
Prepayment Meter (PPM)	**Automatic Meter Reading (AMR)**	**Demand Side Management (DSM)**	**Automatic Meter Management (AMM)**
|	|	|	|
IEC 62055-xx TC13 WG15	IEC 62056-xx TC13 WG14	IEC 62054-xx TC13 WG11	IEC 61968-x TC57 WG14
|	|	|	|
CRP/VTC port	FLAG & DLMS	Ripple Control	UCA & CIM

Figure 2: Characteristics of specific smart meter implementations

Recent standardisation efforts have acknowledged the need for coexistence and integration of data from these forms of smart meters and the above working groups have engaged a process of establishing a Common Information Modelling (CIM) language for each form. It is expected that future meter management systems will deal transparently with information streams from each form, and that ultimately, commercial pressures will force the products to merge into a single, simplified smart meter. The remainder of this paper portrays the kinds of smart meter services and technologies that will be deployed. These will need inspiration and standardisation to be truly effective in enabling the level of services that will be demanded by tomorrows consumers.

5. Enabling consumer choice with multi-service meters

Prepayment suffered an emotional backlash when it was first imposed on township communities as it was perceived to be a poor mans solution. Many communities rebelled against this discrimination and utilities were forced to offer a choice of prepayment or conventional supply. Having been given a choice, communities overwhelmingly adopted a prepayment service due to the consumption control provided. As more forms of service emerge, utilities should be able to configure their smart meters to the changing needs (whims) of their customers, without having to visit the site and swap physical assets. The industry needs a standardised method and dataset to achieve this in a secure and auditable way. Typical service alternatives are given in Figure 3:



Service Legend:
CC = Credit control LC = Load control (MAL) SC = Social credit (grants)
TC = Time control UC = Usage control (MPL) RC = Rate control (CT factor)

Figure 3: Service capabilities of a typical multi-service meter

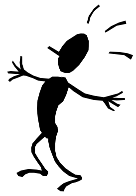
It is beyond the scope of this paper to describe the intricacies of each of the above services, but it is worth noting that the key to the viability of any service control mechanism is that it should be in the customers interest that the control mechanism operates. This ensures that the service will be accepted and adopted by the consumer. Wherever possible, supply disconnection should be avoided and supply capacity restrictions (MAL, MPL) should be used until full service restoration. A multi-service meter should be capable of working on mini-grid or off-grid supplies where the supply frequency is intentionally not stabilised to save on the capital cost of the infrastructure.

6. Enhancing quality of service with multi-function meters

The drive for universal access in developing countries demands that services are extended to remote rural communities. The challenge of providing a safe, sustainable, equitable service to all at an acceptable cost per connection forces the integration of multiple protection measures into a multi-function meter (ECU). In its cheapest form, <u>a multi-function meter is the entire installation</u>, and the utility is bound to incur significant support and maintenance costs arising from malfunctions of the consumers installation and appliances. This seems an expensive luxury.

Naturally, there is substantial resistance to utility provision of such extensive service protection, maintenance and support services from a commercial, logistical and emotional standpoint. It is argued that the utilities responsibility is limited to the provision of a safe (split) metered supply and that further protective measures are the responsibility of the consumer, particularly when the consumer is not paying for the services delivered.

The consequence of this limited service, is that all consumers are expected to understand the severity of the hazards arising from use of the (invisible) service, to have sufficient knowledge and resources to purchase and install the necessary protective devices, and/or to procure sufficient insurance for any damage that may occur due to inadequate protection. This seems highly unlikely in the case of the child headed home previously mentioned.



The National Electricity Regulator (NERSA) is entitled to impose the provision of additional protective services as future license conditions, when they are technically possible and viable. The provision of such functionality in a meter should therefore be provided as soon as possible, and in a manner that gives the consumer and utility the option to negotiate and structure an appropriate and fair sharing of risk/cost that could vary with time. The features should be programmable and must be able to be disabled. Table 2 indicates the range of protective services that can be incorporated and recommends when they should be activated by the utility to protect the consumer and/or the consumers installation and/or the consumers appliances.

Protective Function	Primary Purpose	Conventional 80A Meter	Prepayment 60A ED	Indigent 20A ECU
Main isolator	Installation safety	No (1)	No (1)	Yes
Over current	Installation protection	No (1)	No (1)	Yes
Fault current	Installation protection	No (1)	No (1)	Yes
Earth leakage	Consumer safety	No (1)	No (1)	Yes
Raised neutral	Consumer safety	Should (5)	Should (5)	**Must** (3)
Over temperature	General safety	Should (5)	Should (5)	**Must** (3)
Lost neutral	Appliance protection	Should (5)	Should (5)	**Must** (3)
Over voltage	Appliance protection	Customer (2)	Customer (2)	**Must** (3)
Under voltage	Appliance protection	Customer (2)	Customer (2)	**Must** (3)
Lightning surge (4)	Appliance protection	Customer (2)	Customer (2)	**Must** (3)

(1) The national wiring code ensures that protection is installed and operational in the installation
(2) Customers must be adequately informed of their risks and mitigation options
(3) Utility must accept responsibility when rural/poor consumers are unable to protect themselves
(4) Surge protection must not be integral to the meter if it is prone to decay and/or catastrophic failure
(5) Should be provided by the utility when proven capabilities exist in the deployed equipment

Table 2: Idealised assignment of utility responsibility for additional protective functionality

To better understand the need for utilities to provide additional protective functionality for rural and indigent consumers, consider the case of a typical family in Africa. Normally, this family would save for three years to be able to purchase a bicycle which is a notable measure of wealth, ridden by men and boys only. In an act of benevolence, the utility arrives, installs and supplies free electricity as part of a social development initiative. The family therefore foregoes the purchase of a bicycle in favour of a television. Research shows that up to 60% of such televisions are destroyed within a year by supply irregularities. The provision of the free service thus has a disastrous financial impact on the poor when adequate protection is not provided.

7. Measures to improve revenue assurance and meter survival rates

It is recognized that improved revenue protection requires more than mere technological improvements in the electricity meter, as;

- supply diversion regularly occurs elsewhere in the supply chain
- most mechanisms are prone to false indications that reduce confidence in them
- there is no substitute for proper, independent audits

Table 3 lists mechanisms that can be provided and records the confidence factor they provide.

The common practice of supply disconnection upon (probable) detection of tampering should be avoided in favor of a detect, record and alert strategy. This minimizes consumer frustration and aggression arising from inadvertent supply interruptions. Table 4 indicates the significance of various meter malfunctions. The amount of meter damage from vandalism and abuse is significant.

Assurance Mechanism	Usage	Application	Confidence factor
Cabinet or cover tamper switch (TS)	Common	25% using disconnect 75% audit counter	Low as it is typically not functional when supply is absent
Imbalance current detector (ICD)	**Growing**	Particularly with BS terminal arrangement	Good, detects load connections to earth with swapped live and neutral
Load switch bypass detector (BVD)	Growing	Not significant (combine with ZCD)	Low, can't distinguish load switch failure from bypassed meter
Zero current detector (ZCD)	Seldom	Not significant (combine with BVD)	Low, can't distinguish load switch failure from intentional jamming
DC current detector (DCD)	Seldom	Not significant	Low, can't distinguish deliberate diode insertion from non linear load

Table 3: Confidence factors of additional revenue assurance mechanisms

% of Total in the Field	Description of Malfunction	Sent to Manuf.	Withdrawn from Service	Commercial Risk
0.25%	Faulty	Yes	No, warranty repair	Low
0.25%	**Damaged (abuse)**	Yes	No, out of warranty repair	Low
0.5%	No fault found	Yes	No, returned to service	Low
1% (estimate)	Faulty	No	Yes	Med
2% (estimate)	**Damaged (abuse)**	No	Yes	Med
10% (estimate)	**Free supply mode**	**No**	**No, not detected**	**High**
20% (estimate)	**Not sealed correctly**	**No**	**No**	**High**
66% (estimate)	None (good meter)	No	No, not required	Nil

Table 4: Commercial risk assessment and significance of meter system malfunctions

It would be worthwhile researching the actual cost of poor service to confirm if the magnitude of commercial risk from improper sealing and undetected tampering is indeed a two orders of magnitude greater than the risk of actual meter failure.

8. Measures to improve metering system dependability

Clearly, the survival rate of meters is highly dependant on the level of service actually experienced by the consumer, which is in turn dependant on the dependability of the metering system. Thus service and support efforts are required to sooth consumer frustration and technical efforts are required to maximise the operational dependability of the complete metering system. Table 4 lists the ongoing technical efforts and utilities are advised to ensure that they have requirements for latest versions of these in their tender documents.

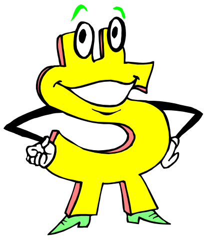
Type Tests	**Compliance Tests**	**Accelerated Life Tests**	**Acceptance Tests**
|	|	|	|
IEC 62052 & SANS 1524	"STS WG7"	IEC 62059 & Eskom ALT	IEC 62058 & SABS Mark Scheme

Figure 4: Ensuring the quality and dependability of metering systems

One worrying factor facing meter manufacturers is the growing incidence of counterfeit components being fraudulently introduced onto their production lines. To gain confidence, it is worth investigating the degree of rigor with which manufacturers screen their incoming materials, and the thoroughness (fault cover) of their production test equipment. This is what minimises embarrassing, confidence destroying and costly recalls.

9. Measures to enhance consumer value and energy conservation

Demand side management features will be incorporated into meters, and it is important to distinguish between utility and consumer initiated measures. Utility initiatives must offer consumers something in return for service restrictions that help the utility manage the generation and distribution of their service. It is extremely difficult to guarantee that benefits passed on to the consumer are actually warranted as the necessary load switching equipment on the consumers premises can have failed or been circumvented. Thus ripple control, radio paging, long wave radio and/or RDS based systems are prone to failure over time.



Consumer initiatives are bound to be more successful. Thus meters will develop a service expansion bus to which consumers may attach a variety of cost saving, energy conserving and service enhancing devices. These devices will draw upon the resources of the meter to provide innovative capabilities and could interact with recognised home automation systems. This bus may also be used by utilities to connect service configuration modules that simplify the logistics of contractual service amendments.

10. Data simplicity, integrity, accessibility and presentation

It is anticipated that an abundance of raw and incompatible data will increasingly be gathered from a diverse array of networks, communication channels and online meters. Whilst the CIM modelling language will help to categorise and condense this data, the resulting information will lack quality if inconsistencies and omissions prevail. The tendency to repeatedly add functionality of increasing complexity within meters must be resisted in favour of a few well defined industry agreed parameter sets. Ideally, meters should only measure and store data and should not include advanced processing capabilities – which are best kept in the domain of the concentrator or better still, located on a central data server. This gives maximum flexibility to adapt services to emerging requirements without recourse to reprogramming or replacement of meters.

Guidelines for maintaining data quality and integrity are;

- avoid all forms of embedded tariffs. These can be intentionally adjusted to incorrect values
- avoid real time data based on clocks. These drift and can be purposely set to incorrect times
- if time functions must be used, ensure time setting is via a automatic synchronisation means
- avoid battery backed data. Data inconsistencies occur as batteries fail or are removed
- use elapsed time based roll over logging that is time stamped upon receipt & never cleared
- provide numerous roll over event counters for common tasks performed or events recorded
- include automatic self scaling profile recorders for all measured parameters
- include energy import and export measurement to cater for future co-generation initiatives

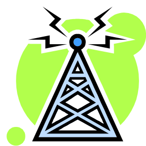
Much work still needs to be done to guarantee seamless integration of all data sources into dependable reports and meaningful billing information for direct electronic access by consumers.

11. Logistic simplicity and lower operating cost

The whole point of moving away from manual meter reading systems is to improve billing accuracy and reduce meter reading costs. The opposite is happening. Utilities are unwittingly becoming slaves to the maintenance of increasingly complex databases that demand perfect and consistent data from a multitude of human based (error prone) business processes. The promised efficiencies are lost in a host of highly skilled interventions and management tasks.

The white paper on service delivery encourages us to search for new and faster ways to provide a better service to citizens. Eleven characteristics of a simple broadcast system[2] adequately provide enhanced service management and revenue extraction through;

- Cost effectiveness (installation and operation)
- Logistic simplicity, fault tolerance and data redundancy
- Non-proprietary, extensible and ubiquitous deployment
- Multi-service and multi application capabilities



Worthy of mention is the IEC 61968-9 committee draft that defines a number of use case actors that share and interact with the operational data systems of a typical utility. These are the;

- Meter technician
- Maintenance scheduler
- Outage management system
- Operator
- Customer
- Customer bill
- Planner
- Meter data manager
- Automated meter reading system
- Meter
- Meter Reader
- Supplier

IEC 61968-9 further defines a number of meter reading and message control types. These are reproduced here as it is expected that our systems will align to these;

- Outage and meter health events
- Customer data synchronisation
- Meter reading & load control
- Customer switching
- Meter installation
- Meter configuration
- Power quality event
- Manual meter reading
- On demand meter read request
- Historical reading
- Meter disconnect and reconnect
- Billing inquiry
- Real time pricing

12. Connecting and integrating all of the pieces

Like it or not, prepayment meters are going online and they are morphing into smart multi-service products. The incorporation of ubiquitous communication channels provides a plethora of new challenges whilst simultaneously opening the door to the cost effective provision of enhanced services to all types of consumers. How soon these can be introduced in sufficient quantities, and how effective they will be in satisfying consumers changing needs, depends on the efforts and skills of those involved in the definition and specification of such products and technologies. Table 5 records the standardisation activities already underway towards this goal and includes additional activities that have been identified, but not yet initiated due to a lack of resources.

13. Promoting global scales of economy

To be truly cost effective, smart multi-service meters must be manufactured in high volumes. They must therefore be designed to international requirements and standards, and must be capable of negotiating a barrage of international trade barriers and intellectual property hurdles. This depends on an open and dynamic, standards based development framework, regulated by appropriate corporate governance and intellectual property policies.

The South African meter manufacturing industry has established such structures and now leads the global prepayment industry. It is well served by the following organisations;

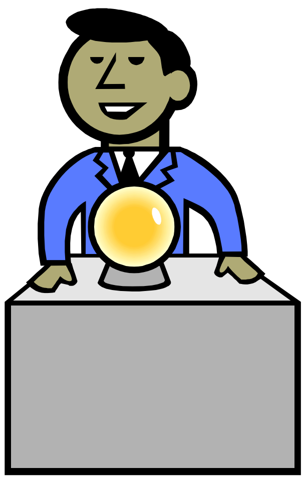
- South African Prepayment Meter Manufacturers Association	SAPEMMA
- Standard Transfer Specification Association	STSA
- Department of Trade and Industry	DTI
- South African Electro-Technical Export Council	SAEEC
- African Electro-Technical Standards Commission	AFSEC

Standardisation Activity	WG and/or Std
Standardised mountings and enclosures	STANSA TC62 SANS 1524-3 (draft) PIESA 1106 (FDS)
Universal meter numbering system and rectification of STS numbering limitations	STANSA TC62 STS WG6 (draft) NRS 057 ? IEC NP ?
Standardised data elements, modelling and messages	IEC TC57 WG14 IEC 61968-9 (CDV)
Improved serial data interface for virtual tokens and meter powered communication modems (wireless)	IEC TC13 WG15 IEC 62055-52 (CD)
Industry standard for accelerated reliability testing	IEC TC13 WG13 IEC 62059-31 (CDV)
Standardised short codes and displays for field support staff	STS NP ? Eskom SCAAA9 (v3?)
STS prepayment systems, compliance testing method and tools	STS WG7 (draft)
STS corporate governance and intellectual property policies	STS WG4 (draft)
STS enhancements for step tariffs and water applications	STS WG3 (draft)
STS global key management infrastructure	STS WG5
STS supply group code restoration process	STS NP ?
Standardised commissioning process	STS NP ?
Multi-service meters, service mode selection method and dataset	STS NP ?
Service configuration modules	STS NP ?
Multi function meters: extended quality of service requirements	NRS 047 ?
Integrated consumer activated demand side management facilities	NRS 086 ?
Improved meter sealing methods and technologies	NRS NP ?
Improved revenue assurance tools	SARPA NP ?

Table 5: Meter standardisation activities supporting improved service delivery

14. Conclusion

At the onset of South Africa's mass electrification programme, Dr Ian McRae acknowledged[3] that services provided to developing communities had to be of equal standard to those of existing customers. In addition to this, it is now clear that the service delivery expectations of existing and emerging consumers are, and will, continually escalate.



Fortunately, tremendous scope exists to improve the quality of service provided to electricity consumers if the industry manages to focus and direct its evolution via open industry standardisation mechanisms. Emerging smart multi-service meters will then empower utilities to adapt and enhance their business processes and practices to meet the challenge, provided that meter obsolescence planning has occurred.

The rate at which these smart meters will be deployed and the time required to establish meaningful quantities depends on the motivation of key players and the commercial opportunities that arise in this market. If these are inadequate to draw resources from other profitable ventures, then much of the afore mentioned will not come into being.

The SANC TC13 committee will provide discussion forums to debate the issues (eg gender specific requirements). When necessary the committee will issue calls for proposals and arrange meetings of interested and effected parties.

Annex A. The SANC TC13 team

This is probably an appropriate time to recognise the ongoing efforts of the members of the South African National Committee of the IEC TC13 meter standardisation committee. This committee devotes substantial unpaid time and effort towards the attainment of improved products and services in the electricity metering industry. Contact details are given, should you wish to discuss matters of interest with them. New members with appropriate experience are always welcome.

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Table 6: Members of the South African National Committee of IEC TC13

References:

[1] White Paper on Transforming Public Service Delivery – Zola Skweyiya, Minister for Public Service and Administration , Sept 1997.

[2] Characteristics of a Simple Broadcast System for use in Domestic Electricity Meters – R Hill, SARPA Conference, 2005.

[3] The Test of Leadership – Dr Ian McRae, Chief Executive of Eskom 1985 – 1994.