Characteristics and capabilities of remote access terminals to improve service delivery and revenue protection of split STS prepayment metering installations

Author Roland Hill, Landis+Gyr (Pty) Ltd
Presenter Harold-John Hayes, Landis+Gyr (Pty) Ltd

Synopsis
This paper describes the benefits of adding remote access terminals to split STS prepayment metering installations. Characteristics of two pilot sites are given to demonstrate the versatility of such systems to Utilities and Consumers. Interoperability and co-existence issues are noted and the end use capabilities of this form of “smart” prepayment system are compared with those of emerging “smart” AMI meters.

1. Introduction
Prepayment metering has a long and successful history in over fifty six countries around the world. The incompatibilities and un-reliability of early systems have been resolved through the standardisation efforts of Eskom in the early 1990’s and by the STS Association in the early 2000’s. The technologies and associated products have since matured into highly cost competitive devices, compliant with over sixty international, regional, national and industry standards.

The focus on quality and dependability continues with the pending release of the STS 501 series of conformance standards and the national efforts to register the IEC 62055-31 standard under the IECEE conformance scheme. These efforts serve to minimise the disruptive consequences of non-compliant product in systems that are becoming increasingly integrated and inter-connected as we move rapidly towards the “smart” grid.

Unfortunately, despite all of the above, non split / single part STS prepayment meters have one serious limitation, in that they must be placed in a location accessible to the consumer; so that the consumer can enter the digits of the STS credit tokens and view their amount of credit remaining. Valiant efforts to define better sealing standards and enhanced codes of practice for revenue protection practitioners have always been thwarted by the need to undertake a “home invasion” to access the prepayment meter for auditing and inspection purposes. Two-way token systems such as smart cards, offer marginal additional protection against tampering and bypassing of a meter fitted in a home and they introduce additional logistical and electrical failure mechanisms. Such systems have failed to gain support in the STS market and none have been standardised.

The STS prepayment industry has made a fairly rapid transition to split prepayment meters where the measurement and load disconnection functions are located in a secure enclosure, remote from the consumer’s premises. A simple and cost effective consumer interface unit (CIU) is then fitted in the consumer’s premises for the purposes of entering credit and viewing the remaining credit balance. The measurement and control unit (MCU) of the split metering installation is then designed to communicate with the CIU, typically via a wired, twisted pair connection or a more convenient power line communication (PLC) technology. Figure 1 below illustrates the difference between single part and split prepayment meters.
Split prepayment meters are inherently more secure and less prone to tampering than single part meters. This comes at additional cost, depending on the communication technology used between the parts. Split meters using dedicated twisted pair wires, are typically double the cost of a single part meter and split meters using power line communication (PLC) are typically triple the cost of a single part meter. Thus single part prepayment meters still have a significant market share in communities where energy theft and tampering is not prevalent (Yes, they do exist!).

Tampering of the metering part (MCU) of a split meter will typically be done in full view of the community at a kerb side enclosure or at the top of a tall pole, which is much less likely than when a single part meter is fitted within the customer’s premises. Unfortunately, it is often impossible to tell the difference between a Utility staff member performing maintenance duties on a pole top MCU, to a revenue theft syndicate member bypassing a MCU for personal gain. The visibility of the meter tampering activity is thus not a great deterrent.

Placing meters on top of a pole makes access for tampering purposes more difficult, but the hardened criminal is not really put off. It is often said that pole top meters simply create a market for ladders and make the life of the Utilities maintenance staff more difficult and less effective.

Furthermore, a home owner or consumer can be held legally liable for damage to, or tampering of, a single part prepayment meter when it is fitted within his/her premises, as he/she has authority over who has access to the single part meter. This is not the case when the MCU of a split meter is installed in an enclosure in a public place as it is almost impossible to prove who performed any tampering that occurs.
Split meters do however; have some significant advantages over single part meters:

1. **Ease of auditing**: Bypassing of the meter must now be done upstream of the MCU part which is now in a remote public location. Auditing, detection and removal of illegal bypass conductors can thus be performed without the hazards and disturbance of a “home invasion”. The value of this ease of access to the MCU, more than justifies the additional cost of the split meter configuration, albeit at the increased risk of unauthorised alterations and loss of legal accountability of the consumer.

2. **Remote asset protection**: The consumer has no reason or right to access the MCU, which means that it can be located in a highly secure enclosure i.e. one which is able to selectively control and record who is granted access to the meters for “maintenance” purposes. This is done with a remote access control system to prevent the theft of enclosure “keys” or seals from dependable Utility staff. Access is remotely granted and logged for recognised personnel and purposes only. Reliance on simple meter seals, tamper switches and terminal covers on meters within a non secure enclosure, are not as effective and may be compromised by the Utility staff tasked to maintain such equipment.

3. **Remote revenue protection**: It is possible to remotely monitor and control the performance of the meters, particularly when a PLC technology is used to communicate between the parts of the split meter. The information thus gained has many applications and advantages to the Consumer and to the Utility, as described in the remainder of this paper.

### 3. Remote access topologies

It should be obvious by now that split meters alone, do not provide adequate levels of revenue protection. The additional cost of the split meter format is warranted, but to be truly effective, it must be supplemented by add-on remote access capabilities in order to provide a truly secure “smart” STS prepayment metering system.

The add-on nature of such remote access capabilities exploits the communication facilities inherent in the split meter design and more significantly, allows the remote access products to be installed, maintained, upgraded and replaced without the knowledge of, or inconvenience to the Consumer.

Furthermore, the commercial justification of the remote access equipment can be independently assessed and motivated depending on the level of tampering prevalent within a specific community. This benefits the revenue protection practitioner as the investment into such equipment can be made long after the initial electrification of the sites, and it can be adjusted periodically if necessary, to match the degree of tampering known to exist at a point in time.

The topology of a remote access system is dependent on the capabilities of the communication technology used between the MCU and CIU of the split meter and the location of the MCU’s within a particular site.

The location of the MCU’s is typically arranged in one of two categories:

1. **Clustered Meters**: This is typical of pole top enclosures and kerb side kiosks. A limited quantity of meters (typically 4 or 8, up to a maximum of 32) is located in a single secure enclosure. The integrity of the meters is protected by a remote asset protection system at each enclosure.

2. **Distributed Meters**: These meters may be fitted in an enclosure similar to the clustered meters, but importantly, may also be located in existing homes, distribution boards or meter rooms in offices and multi-tenant buildings. These are more likely to be managed via a remote revenue protection system fitted at a distribution transformer or sub-station.

![Figure 3: Example of a clustered meter enclosure using PLC or wired split prepayment meters.](image)

The communication technology used between the MCU and CIU typically falls into one of three categories;

1. **Wired**: The STS split prepayment industry has standardised on a two conductor, twisted pair arrangement that may or may not be incorporated into the service delivery cable to the Consumers premises. Wired systems are the most cost effective form of split meter communication, but they are prone to failure from high winds, poor terminations or copper theft syndicates seeking to replace an
2. **PLC:** The STS split prepayment industry has standardised on the use of the IEC 61334-5-2 FSK technology as it conforms to the EN 50065-1 spectrum and emission level limits. Some manufacturers have mistakenly implemented systems in the CENELEC C band reserved for consumer applications, rather than the preferred CENELEC A band reserved for Utility exclusive use. Both are prone to interference from “rogue” appliances swamping the bands with interference. Distances of 100 to 200 metres are typical and hopping and mesh networks are not used, in order to keep costs down. Baud rates are typically 1200 bps due to the frequencies available in the CENELEC A band.

3. **RF:** The STS prepayment industry has not yet standardised on a RF technology as there is no Utility exclusive spectrum available, and there is some uncertainty around the coexistence issues in the available ISM bands. Mesh systems have yet to prove themselves in this cost sensitive market.

Various topologies of remote access systems are thus possible depending on the nature of the site and the communication technology used within the split meter. Multi-part prepayment meter standardisation efforts by the IEC TC13 WG15 have not progressed and the future of the IEC 62055-32 specification is uncertain due to the ever expanding requirements of the smart grid. It is thus necessary (at this time) for Utilities to allocate sites to specific manufacturers to avoid coexistence issues between various remote access systems.

4. **Examples of remote access solutions**

Figures 4 and 5 give graphic representations of remote access solutions for clustered and distributed meters.

**Figure 4:** Example of a remote access solution for clusters of 2 to 30 prepayment meters

**Figure 5:** Example of a remote access solution for sites with 20 to 300 distributed meters
Remote access terminals differ from the traditional data concentrators used in AMR systems. The primary purpose of a RAT is to provide an access path to the data in a prepayment meter, for auditing and revenue protection purposes. Used properly, they therefore do not need the back-haul bandwidths typically associated with AMI data concentrators. This helps to reduce their operational data transfer costs. Whilst capable of much of the data transfer functionality of advanced AMI systems, a remote access solution is intended to be simpler to use and maintain. It is therefore provided with basic AMI functionality only.

5. Capabilities and use cases of remote access terminals

The capabilities of a remote access terminal can be classified into five primary use cases as follows;

1. To provide advanced on-line prepayment services to Consumers, such as;
   a. Automatic credit token transfers (from PoS to meter)
   b. Monthly bulk distribution of free basic electricity tokens
   c. Improved understanding of inclined block tariff charges (at PoS)

2. Alternatively, to provide basic AMI credit metering services to Consumers; such as;
   a. On demand or scheduled meter readings via an internet or mobile website
   b. On-line energy and demand monitoring via an internet or mobile website

3. Remote service monitoring and management for Utility support staff, including;
   a. Outage detection and restoration verification
   b. Power reliability and quality of supply monitoring
   c. Remote service reconfiguration (prepayment vs credit mode)
   d. Remote service interruption and restoration (collections and moving in/out)
   e. Meter maintenance and asset management records (repair records)

4. Revenue protection and energy theft detection for Utility revenue loss staff, including;
   a. Logging and escalation of meter alarms and alerts (e.g. tamper switches)
   b. Auditing of energy purchased vs energy consumption profiles
   c. Detection of ghost meters and vending systems
   d. Detection of fraudulent meter bypassing and/or reconfiguration
   e. Monitoring of supply group, tariff index and key change information
   f. Interface to kiosk controllers and asset protection systems

5. Remote load management and demand reduction for Utility DSM/DR goals, including;
   a. Remote activation/configuration of energy limiting modes (if provided)
   b. Remote setting/adjustment of maximum power limit threshold
   c. Control and programming of remote load switches for DSM (if fitted)
   d. Energy balancing/comparison with ZMD check meters (if fitted)
   e. Interaction and coupling with AMI and Ripple Control systems (at head-end)
   f. Interval and register data reading (e.g. STS 201-15.1.0 register table)

A well designed RAT will be able to provide access to the following STS standard data registers;
- Meter serial number (DRN)
- Available credit register (kWh)
- Accumulated energy consumed register (kWh)
- State of internal load switch (open/closed)
- Maximum power limit threshold
- STS key type & revision number
- STS tariff index
- STS supply group code
- Meter firmware version

Typical features that should be provided by a remote access terminal are;
- Operation on three phase supplies with various earthing schemes
- Self discovery and remote access of PLC split prepayment meters
- Remote access of wired split prepayment meters via the meter’s optical interface
- Modular communications facility with support for GPRS and Ethernet as a minimum
- Ability to load STS tokens into a prepayment meter from a communications controller
- Notification and logging of meter tamper events and alarms
- Real time clock for date/time stamping of all meter events and alarms
- RAT event notifications (such as phase failure or low backup battery)
- Last gasp power failure notification from the RAT to the communications controller
- Liquid Crystal Display for programming and interrogation purposes in the field
- LED communications indicators showing communications per phase (diagnostics)
- Menu scroll and command execute buttons (to access features and functions)
- Two inputs, typically used for sub-station or meter kiosk door switches
- Two system controlled outputs, typically used for alarms linked to inputs
- USB port for local data transfer to memory sticks (on site auditing)
- Interfaces to known Industrial & Commercial meters for the purpose of “check metering”

6. **Capabilities of back end communication controllers**

It is necessary to provide a *simple and intuitive interface* to the many capabilities of a remote access solution and important for the industry to rationalise these into a common set of use cases based on standardised information models used within the Utility. The activities of the IEC TC57 WG14 committee and the common information models being developed are valuable tools to manage the growing complexity of multi-vendor integration layers that are necessary when integrating remote access solution from various manufacturers.

Figure 6: Example of a back end communications controller showing the “health” of 7 RAT’s
Figure 7: Example of meter specific data showing a tampered meter that is out of credit

Figure 8: Examples of half hourly consumption data from the STS available credit register

Figure 9: Example of half hourly maximum demand data from the STS instantaneous power register

7. Characteristics of Pilot Site 1
The site selected was a three storey block of flats with low to middle income tenants using an average of 250kWh per month. One hundred PLC meters were installed with a maximum Meter to RAT communication distance of about 100 metres. Reliable communication was established with all of the meters.
8. Characteristics of Pilot Site 2
The selected site has approximately 220 houses fed from three MV Mini-substations. The RAT was installed on one side of mini-substation. All cabling is underground. Reliable PLC communication was confirmed with all of the meters connected to the mini-sub.

9. Inter-operability and co-existence issues
Split prepayment meters and smart prepayment solutions are designed for cost effective electrification of rural communities. They therefore avoid use of complex communication stacks capable of negotiating network conflicts and similar co-existence issues. They also use low bandwidth technologies as they do not have to deliver the vast quantities of profile data expected of smart AMI systems, nor do they have to perform to tight response times and communication latencies for high levels of interactivity or fast emergency response times. Such technologies are well proven and standardised (e.g. IEC 61334-5-2 FSK PLC) and most have negligible co-existence or inter-operability capabilities as they are usually applied universally throughout a site.

It is thus common practice to allocate specific smart prepayment sites to particular manufacturers serviced by one or more RAT’s capable of interfacing that manufacturer’s communications controller to any and all of the portfolio of metering devices supplied by that manufacturer. The onus is thus on the manufacturer to ensure that their remote access solution(s) is/are compatible with their entire portfolio of STS metering products. This is
consistent with the draft IEC 62055-32 multi-part payment metering standard. This draft purposely does not attempt to standardise the intra-part communication technologies of multi-part STS prepayment systems.

Competition between manufacturers occurs on a site by site basis according to normal tender procedures. Manufacturers are not able to get a Utility wide lock-in on a particular technology except if the head end support of the communications controller is not able to integrate with those of other manufactures or other Utility systems. Should the Utility desire to deploy remote access solutions from more than one manufacturer, the onus will be on the Utility to ensure that the equipment from the different manufacturers are able to coexist at that particular site. Should co-existence problems occur during installation or thereafter that can’t be resolved between the parties, then ICASA will be called in to arbitrate on the legitimate use of the PLC or RF spectrum and to confirm compliance to legislated EMC requirements. The draft NRS 094 PLT guide for power system operators, provides guidance on the technical, operational and contractual factors that Utilities need to consider.

Emerging communication standards promise to include versatile co-existence capabilities via an Inter-System Protocol (ISP) such as the G.cx standard proposed by ITU-T and IEEE. Such protocols and standards are not yet mature and they will take time to stabilise... and to be widely adopted amongst manufacturers ... and to reach significant quantities in the field.

10. Data privacy and security

Smart STS prepayment solutions are built upon the security services of the IEC standardised STS technologies. As such, all credit transfers and engineering tasks are adequately encrypted to an appropriate level of security. The key management infrastructure to deliver this has matured to cater for a global distribution of cryptographic keys in a highly secure and co-ordinated manner. Utilities are encouraged to use the on-line vending security capabilities in the soon to be published SANS 1524-6-10 on-line vending standard. Security capabilities always rely onto two strategies, namely robust data encryption to prevent compromise of the data transferred, and thorough auditing processes to detect when data has been compromised. The remote access solution has considerable value to the latter strategy.

11. Integrating smart STS prepayment and AMI metering solutions

Maximising revenue collection and improving service delivery to communities is all about listening to and flexibly responding to the needs of a community down to the level of individual preferences. This dictates that modern Utilities deploy systems capable of offering Consumers a choice between various service alternatives.

Modern STS prepayment meters are capable of operating in a prepayment mode or a credit metering mode. Thus specific individuals in a community fitted with STS split prepayment meters, may be offered a basic credit metering service when a RAT is deployed to remotely read the meters. The smart STS prepayment system thus functions as a low cost AMI metering system via the communications controller described in section 6.

Although smart STS prepayment systems comply with the definition of a “smart system” given in RSA Government Gazette R773, and hence may be used for Consumers with an average monthly energy consumption of greater than 1000 kWh per month, they do not provide the high levels of advanced tariff and energy efficiency services that a fully standardised NRS 049-1 smart AMI metering system requires. Smart STS prepayment systems are thus ideal for the low consumption users as contemplated in the NRS 049-2 standard being prepared. In such low income applications, Utilities can implement credit control policies that remotely switch credit based Customers to a prepayment service when they run into financial difficulties – and switch them back again, when appropriate, without a site visit or a physical swap out of the meter.

Utilities also need to cater for Consumers in a smart STS prepayment site, who will demand an electricity service offering greater flexibility in tariff selection and/or enhanced load management and information display capabilities – such as those provided by modern smart AMI solutions based on the DLMS suite of standards. This request can be accommodated by replacing the split STS meter...
with a smart AMI meter having a GPRS modem communicating directly to the Utilities head end AMI system.

The Utility is however, then faced with the logistics of transferring the Consumers account between the smart prepayment and AMI head-end systems - unless the Utility has invested into an integrated head-end system compliant with the evolving IEC 61968 Common Information Model (CIM). It is expected that Utilities will make significant investments into multi-vendor integration layers to manage the provision of a diverse set of services to Consumers with various forms of smart STS prepayment systems and smart AMI systems so that these may be managed and controlled via messages conforming to the present and emerging IEC 61968 series of standards. Such integration work will be substantially simplified when advanced AMI meters are procured, compliant with the emerging IDIS specification. IDIS is an abbreviation for “Interface Definition for Interoperable Systems”.

12. Conclusion
The combination of proven STS split prepayment metering technologies with complimentary Remote Access Terminals and Remote Access Solutions provides enormous benefits for Utilities and Consumers. Revenue protection programmes can now advance to more effective online methods and avoid the conflict and disruption of home invasions. The question now is;

Can you afford NOT to fit remote access terminals to all your split STS metering installations?

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