

Metering for Small-Scale Embedded Generation

Information to help municipalities understand and procure suitable SSEG metering systems.

September 2019

Abbreviations

AMI	Advanced Metering Infrastructure
AMR	Automatic meter Reading
DC	Data Concentrator
DLMS	Device Language Message System
PLC	Power Line Communications
SSEG	Small-Scale Embedded Generation
STS	Standard Transfer Specification (secure message protocol between a POS and meter)
TOU	Time of Use

Overview

To enable Small-Scale Embedded Generation (SSEG) on municipal grids, electricity meters must support bi-directional metering with separate import and export energy registers¹. Such meters may be prepayment or post-payment (i.e. credit meters). In the case of meters employed in post-payment mode, the billing systems must support reverse-feed tariffs. In the case of smart prepayment meters, they must support the configuration of charges for export energy. In order to accommodate SSEG, municipalities should therefore specify and procure the latest generation meter technologies that support SSEG, or at least prescribe the minimum specification of meters to be installed by a third party.

Smart meter technologies typically include communications infrastructure either via data concentrator devices or point-to-point communications with a smart meter back-office system (described later). This infrastructure is typically referred to as 'Advanced Metering Infrastructure' (AMI). The AMI system offers significant benefits to the municipality because it provides two-way communications to enable remote reading of import, export and other

TO ENABLE SSEG ON MUNICIPAL GRIDS, ELECTRICITY METERS MUST SUPPORT BI-DIRECTIONAL METERING WITH SEPARATE IMPORT AND EXPORT REGISTERS.

IF A MUNICIPALITY DOES NOT HAVE SMART METERING COMMUNICATIONS INFRASTRUCTURE IN PLACE, NOR INTENDS TO, SUITABLY CONFIGURED BI-DIRECTIONAL PREPAYMENT METERING MAY BE APPROPRIATE FOR SSEG CUSTOMERS.



¹ Unless reverse-feed is being blocked, which is generally not advisable for technical and financial reasons (there are no standards for such blocking; load-generation matching is more likely with potential anti-islanding complications; and it is financially beneficial to accept export power and on-sell it with a profit margin)

important energy registers with respect to SSEG.

Smart meters can have an important role in **fraud detection**, load management and power quality monitoring, amongst other areas. A key motivation for installing smart meters often revolves around their fraud prevention abilities. While this and other functionalities and benefits are important to consider in smart metering programmes, this guide focuses on their role with respect to SSEG customers mainly.

SSEG metering without AMI communications

Where municipalities are procuring SSEG-compatible meters but do not have AMI communications infrastructure in place, nor intend to in the medium-term, suitably configured bi-directional prepayment metering may be appropriate for SSEG customers.

However, because of the potential future benefits of smart meters, municipalities currently without AMI communications infrastructure could consider using smart meter technology that has the option of being operated in an off-line configuration, where the meters are able to support separate import and export registers, and in the case of smart meters in the prepayment mode, to enable the configuration of the charge registers such that they do not deduct the prepayment account for export energy. At a later date when the municipality adds the AMI communication system components, the installed meters can integrate into an AMI environment that enables two-way communications and remote configuration of export register charges, thereby unlocking the significant capability and long-term benefits that smart meters are able to offer.

SMART METERS FOR SSEG CUSTOMERS WILL NEED TO BE INTEGRATED INTO THE MUNICIPAL SMART METERING STRATEGY, INCLUDING THE SMART METERING COMMUNICATION SYSTEM.

What is a Smart Meter?²

A smart meter is an electronic device that records electrical energy consumption and reverse feed of electrical energy, amongst other parameters, and communicates the information to the electricity utility for monitoring and billing. Smart meters support the recording of energy in load or billing profiles which are able to be configured with various capture periods, typically every 30 minutes, daily or monthly. Smart metering as a part of an AMI system differs from automatic meter reading (AMR) in that it enables two-way communication between the meter and the municipal systems. Communications from the meter to the network may be wireless, or via fixed wired connections such as power line carrier (PLC). Wireless communication options in common use include cellular communications (e.g. 3G or GPRS using SIM cards), radio, or various forms of Wi-Fi.

While smart metering has been used for commercial customers for several years, latest generation smart meters are available for single and three-phase residential customers, support both prepaid or post-paid modes, and are available at reasonable cost.

Smart meters typically support **four quadrant energy measurement** - i.e. measuring both active (kVA) and reactive (kVAr) power for both forward (import) and reverse (export) power flow. Even single phase residential smart meters tend to support 4-quadrant measurement, although reactive power values are not currently used for such residential customers.

Other potential benefits of smart meters include supporting the reduction of peak load, for example by sending pricing signals to appliances and generators.

² Some text taken from Wikipedia

Communication systems for smart meters

The smart metering communication system both feeds consumption information to the utility billing system in an appropriate format and enables the municipality to change the parameters (such as ToU periods) or modes of operation (such as from pre-payment to post-payment) of the meter, amongst other abilities. The communications system for SSEG customer smart meters should be part of broader municipal smart-metering planning, as it will be difficult to justify establishing such a system for relatively small numbers of SSEG customers. Smart meters commonly communicate in the following two layouts:

Power Line Communication (PLC) via data concentrator (DC) at mini-substation: when there are many smart meters in an area this option is more cost-effective than point-to-point communication (a DC typically may cover about 150 meters, and a minimum number of meters for viability might be around 50). However, in instances where there are only a few such meters (for example if smart meters are only being installed for SSEG customers who are few and far between) this is often a more expensive option on a 'per customer' basis because of the cost of the DC. PLC linkages between the meter and DC are not always direct but may be via other communication layouts (mesh, peer-to-peer etc).

Point-to-point (typically via 3G/GPRS cellular network) – smart meter to utility 'head end': this requires that each meter has a dedicated modem installed for such communication, which adds to the cost of the installation. Such a modem (excluding the meter) may cost between R2000 to R4000³, although lower cost options are available and are accommodated by some smart meters – potentially costing only around R500 (though compatibility between the modem and meter needs to be confirmed with the meter supplier).

Bi-directional meters (smart and non-smart)

Some characteristics of a range of bi-directional meter types are given in the table below.

Meter category	Comms	Cost (indicative)**	Pros	Cons
Prepayment* (STS) meter 1-ph with separate reverse flow measurement (not 'smart')	none	Lowest cost (~R1400)	Simple, affordable option suitable for small SSEG customers. Charges for export energy may be configured so as not to decrement the prepayment account	Any changes to the charge register or other meter parameters will require on-site configuration (via the meter's optical interface)
Prepayment* (STS) /post payment 1-ph smart meter, 4-quadrant measurement	PLC to data concentrator (no modem needed) or wireless point-to-point using e.g. cell network modem. Can optionally be used in an off-line configuration without communication, but this negates the	Medium cost (~R2000), with additional cost if modem needed (~R500 – R2000) or portion of the amortised cost of the DC	Two-way communications: remote reading of export and import registers and prepayment credit registers for SSEG, remote modification of charge registers, TOU, tariff or other important meter parameters, remote	Requires investment in AMI infrastructure and communications (however if used off-line in prepayment mode, the charges for export energy may still be configured to not decrement the

³ Indicative prices for October 2018

Meter category	Comms	Cost (indicative)**	Pros	Cons
	benefits of smart metering	per transformer	change of the meters account between prepayment or post-payment, remote disconnection and reconnection of the meter's supply control switch, significant reduction of operational costs and improved revenue protection for the municipality.	prepayment account)
Prepayment* (STS) /post payment 3-ph smart meter, 4-quadrant	PLC to data concentrator (no modem needed) or wireless point-to-point using e.g. cell network modem. Can optionally be used in an off-line configuration without communication, but this negates the benefits of smart metering	Higher cost (~R4000)	Prepayment meter options may be used for all high end residential and commercial three phase customers within the maximum per phase current limits of the selected meter types The above mentioned pros for the 1ph smart meters also apply.	Requires investment in AMI infrastructure and communications (however, if used off-line in prepayment mode, the charges for export energy may still be configured to not decrement the prepayment account)

* - These Prepayment meters are generally available in split configuration as well as integral units.

** - Cost estimates as of October 2018 (NB: varies substantially depending on specific supplier)

EXPERIENCE WITH SMART METERING PILOT PROJECTS

Various smart metering pilot projects have been undertaken in South Africa since early 2000's, including at City Power (Smart metering), Eskom (AMR, tamper detection, residential ToU), SANEDI (municipal revenue protection) and eThekweni (Active Network Management of SSEG). Lessons for municipalities include⁴:

- A serious skills gap exists at many municipalities regarding such metering – even around approaches to basic bi-directional metering
- Confusion around differences between Smart Grids and Smart Meters exists
- AMI meter procurement is challenging for municipalities in spite of the existence of relevant standards and some procurement guidelines
- A customer-centric approach is important, emphasising communications and buy-in

⁴ Information in this section from: SEA 2015. Smart metering: Overview and Considerations for South African Municipalities. SAMSET. www.cityenergy.org.za.

CASE STUDY: Polokwane Municipality - proportional reverse feed energy deductions: Latest generation smart meters have the capability to set charges for export and import energy registers. These charge registers may then be configured to either deduct, be neutral or add energy back to the meter's prepayment account. A particular case used by Polokwane Municipality is to have their smart meters configured to pay a percentage of export energy back to the meter's prepayment account as compensation for exporting energy (they have initially set the proportion to 30%) - the actual amount of exported energy is not recorded resulting in an administratively simple solution for reverse-feed accounting. In other words, the billing system does not need to be changed. In order to ensure future adjustment of the proportional charge deduction per unit of export energy, it is advisable that municipalities select metering technology and AMI systems that are able to support remote tariff adjustment as SSEG tariffs evolve over the years. (Note that this 'proportional compensation' method, while administratively simple, will not suit the many situations where the utility wants the reverse feed electricity data).

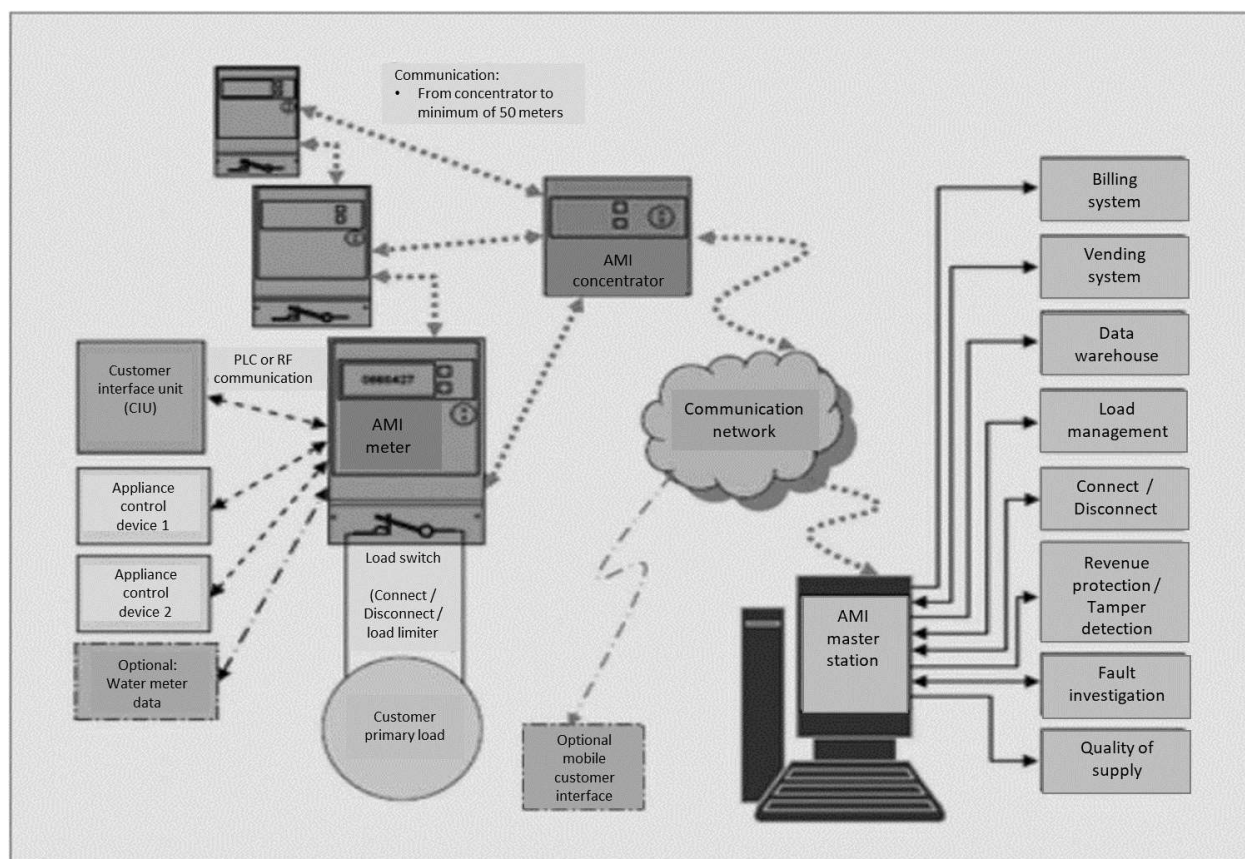


Figure 1: Illustrative AMI communications and functional schematic⁵

⁵ From: Calmeyer 2012. ZigBee as a technology platform for advanced metering infrastructure (AMI). 63 AMEU Convention, 2012.

Procuring meters: standardisation and avoiding vendor lock-in

In procuring meters and AMI infrastructure, standardisation is important in order to avoid potential incompatibilities amongst different components and thus vendor lock-in. The following two documents are of particular relevance in this regard:

The **NRS049 *Advanced Metering Infrastructure Requirement for Smart Metering Systems*** specification provides standards for smart meters, ‘head-end system’, vending systems, customer interfaces etc to promote interoperability and interchangeability of different vendor products, including compliance with relevant international standards and compatibility with emerging technologies such as the ‘internet of things’. **Importantly, it also includes procurement guidance** for these system elements (in Annex B of NRS049). Municipalities are advised to reference this voluntary standard to avoid vendor lock-in. (see Annex A for more information on NRS049)

The **AFSEC *Guide for Application of Standards for Smart Metering Systems in Africa*** provides thorough information on applicable standards to consider in procurement, and is directly relevant to South African municipalities.

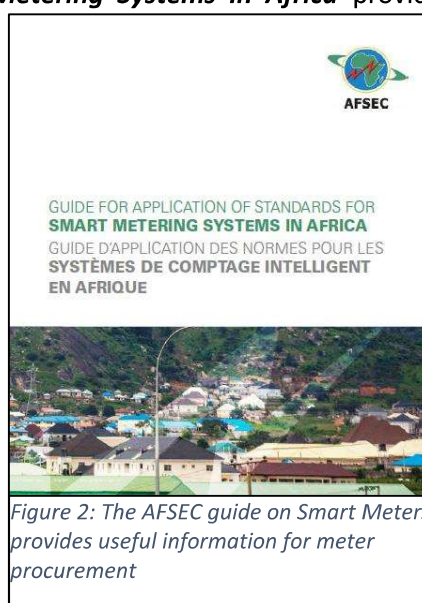
The above documents both refer to and draw on a range of other standards and protocols important for

interchangeability and interoperability, including the DLMS (Device Language Message System) and IEC 61968 series of specifications – which concern standardisation of data interfacing – e.g. head-end system with

billing system. When procuring meters, it is important to ensure that data from the ‘head end’ of the smart meter communication system will be compatible with the municipal billing system (or Enterprise Management System). For example, some municipalities may require a flat file as input into their billing system.

Deciding on data to be collected by the smart meters
Smart metering data collection capabilities are substantial. However, collection of vast amounts of data may not be sensible unless the municipality has the intent and capacity to apply detailed analytic processes. Smart meters and systems do however offer substantial flexibility in this regard and

INTERCHANGEABILITY AND INTEROPERABILITY OF SMART SYSTEM COMPONENTS NEEDS TO BE ENSURED WHEN PROCURING METERS. THE NRS049 AND THE AFSEC ‘GUIDE FOR APPLICATION OF STANDARDS FOR SMART METERS’ ARE VALUABLE REFERENCES IN THIS REGARD.



MUNICIPALITIES SHOULD SPECIFY THE MINIMUM DATA THAT THEY REQUIRE FROM THE SMART METERS, THEREBY ENABLING ESSENTIAL FUNCTIONS AND ANALYTICS, BUT AVOIDING MANAGEMENT OF LARGE DATA STORAGE SYSTEMS WHICH COLLECT MORE DATA THAN THEY HAVE THE CAPACITY TO PROCESS.

meter profiles, events and mains quality profiles may be configured to collect only the data required for municipal processes.

While most smart meters support a standard set of data registers, load profiles, billing profiles, meter events and mains quality profiles may be configured to collect, store and communicate only the desired information. This may be part of the manufacturers initial meter configuration and therefore understanding the capability of the selected metering technology, and defining the meter configuration upfront, should be an essential part of the municipality's procurement process.

SMART METERS SHOULD HAVE THE
POTENTIAL TO ACCOMMODATE
FUTURE NEEDS, INCLUDING
RESIDENTIAL TOU SSEG TARIFFS
(FORWARD AND REVERSE).

Data registers

Typical smart meter data registers and capabilities are shown below:

Energy registers, such as:

- Active energy import (+A) and export (-A)
- Active energy combined (net)
- Apparent energy import / export (VA)
- Reactive energy per quadrant
- Reactive energy import, export
- Active energy import per tariff rate offered by smart meter
- Active energy export per tariff rate offered by smart meter

Instantaneous values, such as:

- Phase voltage, Phase current, frequency, Active Power total (P), Active power import (+P), Active power export (-P), Reactive import power (-R), Reactive export power (-R), Reactive power (Q), Apparent power (S) and Power Factor

Mains quality profiles may include:

- Average voltage (per phase), average current (per phase), average power factor, average mains frequency, average active power import (+P), average active power export (-P) and more.

In addition, meters accommodate ToU tables which identify seasonal, weekly, daily and special day tariff differences.

Many municipalities are considering applying ToU tariff both for energy consumed and energy exported into the municipal grid for residential SSEG customers (some municipalities have done this already). The municipalities should ensure that their smart meters procured have the necessary registers to accommodate these requirements⁶.

Power quality data can be useful for monitoring the impact of SSEG on the distribution grid, and some municipalities may want to utilise these features of smart meters.

Communication failures, estimated readings and data storage

Smart meters generally have storage facilities which can hold several month's data (e.g. 240 days' worth of readings for every 30min) and have internal clocks to time-tag the data where necessary. Data is therefore not compromised during power or communications system outages. Estimated

⁶ Some municipalities may opt for a simple ToU tariff – e.g. 2-part.

readings will generally be unnecessary. (However, the use of some more advanced capabilities of smart metering, such as peak load management, will be compromised at such times).

ANNEX A: NRS049: 2016 Overview and Contents (extract)

ADVANCED METERING INFRASTRUCTURE REQUIREMENT FOR SMART METERING SYSTEM

Introduction

Metering systems have evolved from simple meters, through automated meter reading (AMR) and advanced metering infrastructure (AMI) into state of the art smart metering systems.

With the advent of decreasing component costs, increasing processing capacity and advancing communications inter-connectivity, both in the private and public domain, the paradigm has gradually shifted towards system architectures with distributed functions having local processing power and intelligence, thus affording devices to behave in smarter ways.

NRS 049 presents an "open standard" reference architecture, which means that each entity within the metering system presents a standard interface and a standard semantic. Utilities are thus in a position to optionally and selectively specify any part of the system, or an integration of selected parts into sub-systems, while still adhering to the standard interfaces.

It carefully considers the hardware architecture and function clusters against the following criteria:

- a) life cycle cost distribution of core functions with high utilisation versus optional functions with low utilisation;
- b) reliability and life span of system entities;
- c) mitigation of risk of critical failure and breach of security;
- d) flexibility and extensibility for future proofing;
- e) open international standardisation of core functions;
- f) interoperability and interchange-ability of hardware devices.

The core functions (metering, accounting and load control) are embodied in the Meter.

The customer interface unit offers basic functions to support the Meter operations with optional extensions providing variable degrees of complexity, functionality and cost.

The choice of DLMS/COSEM as the application layer protocol ensures semantic interoperability, flexibility and device interchange ability.

Open international standards supported by formal certification bodies ensures quality of devices and multiple supplier selection, which prevents utility lock-in and stimulates competitive pricing.

Standardising on the "route-over" Network protocol ensures routing capability independent of the lower communications layers. This allows efficient mesh network deployment and compatibility with "internet of things" (IoT) technology using internet protocol addressing.

IEEE standards for the data link and physical layer protocols ensure seamless integration for radio frequency and power line carrier mixed networks.

Functional user requirements are specified in terms of use cases that may be selectively deployed in order to meet particular business objectives. The use cases in turn are supported by abstract function definitions specified in terms of standard DLMS/COSEM interface classes and instantiated objects.

Particular requirements for devices and equipment are specified by reference to international open standards for type testing and conformance certification by recognised certification bodies, thus ensuring quality, reliability and robustness in the application domain.

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Annex D – Meter COSEM objects

Annex E – Appliance control device COSEM objects

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Other resources

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