# Advanced Metering Infrastructure Requirements for Future-Proof Deployments

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# ABSTRACT

Advanced metering infrastructure (AMI) meter deployment has been steadily increasing throughout the world. An AMI meter is one that measures and records usage data at hourly or more frequent intervals and that transmits these data at least daily. The two basic functions of an AMI meter are to make measurements and to communicate these measurements to facilitate the use of the data by both utilities and end consumers in a timely manner. In addition, AMI meters may include service connect/disconnect capability. As part of ongoing AMI research efforts of the Electric Power Research Institute, this paper analyzes some of the factors involved in writing "future-proof" specifications for AMI systems. The Oxford English dictionary defines "future-proof" as "protected from the consequences of future events; especially designed in a manner that provides protection against rapid obsolescence." This paper describes the current state of AMI requirements and highlights five specific areas that are essential to consider when deploying an AMI system.

**Keywords**
AMI
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Requirements
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# CONTENTS

# 1
# CURRENT STATE OF AMI REQUIREMENTS

Requirements for AMI systems today tend to specify what is needed at the moment, but may not include specific requirements to cover future needs. Because the typical expected useful lifespan of a deployed AMI system is ten or more years, requirements should be crafted to encompass the entire expected life of the system to assure maximum return on the investment in the AMI system. The following sections describe the current state of AMI requirements.

## Typical Meter Measurement and Storage Specifications

Meter requirements for AMI systems today tend to cite specific performance and accuracy standards such as ANSI C12.1 and C12.20 or IEC 62052 and 62053. [3] [4] [5] [6] The requirements for the meter typically include the very basic specifications such as voltage, frequency and number of metered phases and expected measurement capabilities such as TOU metering, net metering, load profile capacity, number of profile measurement and instrumentation quantities. Interval resolution for even fine-grained profiling data for commercial and industrial metering applications is most often 15-minute intervals, and sometimes 5-minute intervals, but only in rare cases less than 1-minute intervals. In past years, it was typical for the specification to include some implicit memory sizing requirement such as by requiring that "the meter must be capable of providing and storing the interval meter data for a minimum of 35 days." [7]

Most importantly from the point of view of writing future-proof requirements, these capabilities have only slowly changed over the last twenty years or so and the operational requirement for long-duration storage in the meters is considerably reduced by the use of frequent, automated remote communications with each device rather than the traditional meter reader with handheld and probe physically visiting each meter. The purpose for this requirement in the past has been to allow for the recovery of all data even in the event of a lengthy communications outage. However, data not used for billing purposes, such as voltage profiling data used for distribution operation analysis purposes, may not need to be retained this long. Put another way, there is little need to store forty days of historical profiling data (which is typically not used for billing purposes) in a meter if the head-end system is reliably gathering the data every four hours. Instead, if the specific regulatory environment allows it, the same amount of storage could be used to store a shorter duration of finer-grained data, resulting in little or no net change to the basic meter requirements.

## Typical Meter Communications Specifications

Meter communications typically consist of three categories but not all meters are equipped with all three kinds of communication. The categories are:

1. Local infrared optical
2. Neighborhood Area Network (NAN)
3. Backhaul communications, or Field Area Network (FAN)

The local infrared optical port is very common but optional. It is used for local communications by a meter reader with handheld device and optical probe in direct contact with the device. It is used primarily for configuration and diagnostics and not for regular meter reading in AMI systems.

Neighborhood Area Networks are the core technology that characterizes an AMI system. These networks are most often implemented via a radio mesh, tower-based RF, or powerline communication technology. Generally, a NAN allows the meters to communicate with an intermediary device on the network (i.e. an access point) with only the intermediary having direct access to the utility's head-end system.

The link between the intermediary agent and the head-end system is generically called the back-haul communications link and is often copper telephone line, cellular radio, private radio, or fiber.

Additionally, some devices also include a fourth kind communications channel that participates in a Home Area Network (HAN). When present, a HAN is often ZigBee or similar radio protocol and is intended to relay data on behalf of the utility to devices inside the consumer's home or business. The Smart Energy Profile (SEP) version 1.0 was released by the ZigBee Alliance in 2008 and an updated 2.0 version was released in 2010. The Alliance made a number of changes between the two, even though the underlying RF standard most often used for metering was not changed. The changes were generally to add features to the profile and to improve security of the protocol. However some device manufacturers found that ZigBee chips incorporated into their products to implement the version 1.0 standard did not have sufficient available code space to accommodate the full 2.0 specification, thus such devices could not be updated.

### System Requirements

The system requirements for AMI system components other than the meters most often describe communications and software. The communications requirements may include overall system communications capacity at the head end (such as number of simultaneous communications supported and the aggregate throughput of all channels) and describe performance and interface specifications for the software. Because the basic function of an AMI system is the collection of billing data, this is the application that drives most of the requirements for the AMI system today. [8]

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# REQUIREMENTS IMPLICATIONS FOR FUTURE-PROOF SPECIFICATIONS

The ability to write future-proof specifications depends on the ability to anticipate the future. The two things typically affected by changes over time are:

1. Increased memory required
2. Increased throughput required

We can confidently predict that future needs will drive the need for more memory and more communications throughput based on decades of history even without knowing which *particular* factors will force these changes. However there are certainly potential future states that can be anticipated and evaluated during the requirements-writing stage that may assist in evaluating how much additional memory or throughput might be required over the useful lifetime of the system. Among the possible changes that can be anticipated are:

1. Advances in distributed intelligence within the distribution network
2. Ability to add new logic or intelligence in the meter and access points
3. Flexibility of communications for upgrade to new media and protocols, or to simultaneously support multiple protocols
4. Additional or higher quality measurements to allow more detailed metering or to supplement metering data (such as temperature data)
5. Cybersecurity updates of deployed devices

The implications of each of these is considered in individual sections below.

## Advances in Distributed Intelligence Within the Distribution Network

As utilities and manufacturers work toward a more efficient grid, one trend that has emerged is the distribution of intelligent agents within the power distribution network. [9] [10] As this extends to metering, it is probable that meters will need to provide their data to more and different devices, such as load tap changers, recloser controllers and cap-bank controllers, and to provide data more frequently. For this reason, the communications infrastructure for AMI will need to be able to gracefully support more than simply billing-related traffic. This means that the percentage utilization of the available payload bandwidth for an AMI system should be much less than 100% when used for solely AMI purposes. While the specifics of how to measure the network utilization will vary by communications topology and protocol, the underlying system must allow for a means of measuring and reporting the network utilization. This suggests that a future-proof specification should require network utilization measurement and reporting. EPRI is currently researching how to specify utilization requirements and also identifying other important technical factors such as the ability of the network to provide traffic separation via Quality of Service (QoS), routing algorithms and other techniques.

## Ability to Add New Logic or Intelligence in the Meter and Access Points

Work is currently being done to allow for meters and other smart grid devices to serve as the platform on which currently unspecified future applications may be run. [11] For devices to be able to run both the application platform itself as well as applications atop the platform, they will need to be provisioned with more than enough CPU capacity[1], ROM[2] and RAM than are required to meet current metering needs. Experience has demonstrated that firmware costs rise exponentially when system resources are more than 75 to 85% full, so requirements should specify that some unused resources must be available to accommodate future needs. [12] In the context of AMI, this implies not only that the initial system resource capacity should be less than 85% full, but that this capacity should not be exceeded over the useful lifetime of the system. The structure of RAM as implemented in current microcontrollers is such that it is often the largest physical feature on a semiconductor die, and therefore a primary contributor to the overall cost of the device. However, microprocessor costs for 3-phase power metering typically represents less than 10% of the cost of a meter. Some metering devices have already implemented separate metering and communications processors which tends to make the circuit board more crowded and more complex to design and manufacture, but this adds flexibility at some additional expense over a corresponding single-processor solution. The requirement, therefore, should be that some percentage of system resources, memory in particular, should be available for future use. Study of the particular patterns of code growth and data storage growth is an area of ongoing EPRI research.

## Flexibility of Communications for Upgrade to New Media and Protocols

Metering requirements have changed much more slowly than communications over the past decades and this trend seems likely to continue. While it is not possible to remotely download new hardware to meters and radios deployed in the field, the head-end software should be sufficiently flexible to allow for changes in the underlying communications media.[3] For example, as more fiberoptic communications is deployed to individual homes, it may, in the future, be economically viable to either share fiber bandwidth or use dedicated fiber for AMI systems. While it is unlikely to be economically rational to pre-deploy fiberoptic communications modules with every AMI meter, it does make sense to allow for that possibility within the head-end software. If the software is too tightly coupled to the underlying network structure, the result is a system that is inflexible and incapable of adapting to future communications media and protocols. For this reason, AMI system software should be required architecturally to be able to support multiple communications media and protocols.

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[1] The capacity of CPUs is often approximated using clock speed or how many Millions of Instructions Per Second (MIPS) it can process, but what is meant here is more generically the capacity of the processor to do useful work.

[2] The term "ROM" is used generically here to distinguish unchanging firmware storage from true Random Access Memory (RAM). Most current designs store the bulk of their firmware in Flash memory which is technically not "Read Only Memory" in that it rewritable, allowing the firmware to be field upgraded.

[3] While in theory, field devices could be physically retrofitted in the field, economic analysis of this approach including attempts to enhance this capability [14] have generally dictated full device replacement rather than physical field upgrade.

### Additional or Higher Quality Measurements

Today's revenue metering is done by a single meter with one sensor per supply phase. However, several factors suggest that this may not always be the sole model in the future. First, the increased penetration of distributed generation such as solar and wind may drive the need to separately meter power generation and power consumption. This is different from the traditional net metering and would require at least additional sensors if not additional meters. Metering of individual circuit breakers at the customer premise is also a possibility, so the system should be flexible to gathering and collating a plurality of metering readings from a single service. However, to maintain the accuracy and simplicity of having a single revenue meter, it is most likely that such additional sensors would be adjunct to and not replacements of utility-owned revenue metering assets. The requirement implication is that the architecture of the software and communications should be such that the additional data could be transported to and correctly interpreted at the head-end.

### Cybersecurity Updates of Deployed Devices

The most probable future need for any AMI system is the need for security-related updates and patches. Physically delivering and applying a patch to every devices on a large system is clearly economically infeasible, so the only rational alternative is to automatically distribute such changes via the AMI network. Most obviously, this means that smart meters must be upgradable in such a fashion. The NEMA SG-AMI 1-2009 standard, "Requirements for Smart Meter Upgradeability" was written specifically to detail this need. [13] Requirements for AMI systems should require demonstrated compliance with that standard. Less obviously, however, is that cybersecurity mechanisms often depend on encryption and that encryption algorithms within metering devices are often assisted by hardware. For example, many metering ICs provide a hardware implementation of the Advanced Encryption Standard (AES) to speed up what would otherwise have to be done more slowly in software. However, if a flaw were discovered in either the hardware implementation or in the cipher itself, the alternative would have to be implemented purely in software and would therefore execute more slowly. For this reason, while the use of such hardware enhancements is useful, AMI systems should be required to be cryptographically agile without needing to rely on hardware implementations and while still meeting performance requirements.

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# CONCLUSION

While many AMI devices and systems have been successfully deployed and used, writing future-proof requirements for them requires careful consideration of probable future scenarios and a weighing of the costs and benefits of potential requirements to meet them. Among the specific requirements implications identified in this paper are:

1. AMI systems should employ network utilization measurement and reporting.
2. Some percentage of system resources, memory in particular, should be available for future use.
3. AMI system software should be required architecturally to be able to support multiple communications media and protocols.
4. The architecture of the software and communications should be such that additional types and quantities data could be transported to and correctly interpreted at the head-end.
5. AMI systems should be required to be cryptographically agile without needing to rely on hardware implementations and while still meeting performance requirements.

# 4
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