END TO END COMMUNICATIONS for SMART GRID

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Introduction

As the Electric Power Grid is structured today in North America, there are many independent and mostly isolated partitions, termed "Grids" in this paper, each with particular data sensing or data control. While all of these partitions are solidly connected via conductors, breakers and transformers, etc., the partitions are defined by functionality such as consumer loads, distribution, substations, tie stations, generators, transmission and data management/control of each of these. The means of large scale transferring of data between the partitions are difficult with custom and proprietary interfaces. Most of the existing control centers operate with proprietary communications protocols and proprietary data management and control platforms. Data availability necessary for Grid Operations' control of generation, transmission, distribution and consumer loads requires "End to End" communications which is practically impossible given today's circumstances. For a variety of historical and market reasons, the grids in North America have been built — arguably they have mutated — as an unfortunate "Balkanized Tower of Babel" The SmartGrid is largely a software project with the alignment needed of the millions of Distribution and Transmission devices to the communications standards appropriate for their partition requirements. Such systematic communication is crucial for the success of the Smart Grid [BBG+08]. Yet the necessary interoperability across this wide geographic scope is unthinkable given this current state of affairs in data communications for our power grids.

The few instances of utilizing communications standards have sustainability problems because of obsolescence or lack of device compliance to the very standards intended for interoperability. Standards alone cannot produce interoperability, even in the best of worlds.

A uniform device compliance mechanism must be incorporated. Utilities are becoming aware of the needs to upgrade their systems for a more intelligent Grid. The obvious needs for better reliability and upgrading to accommodate national objectives such as energy independence must still fall within the bounds of successful business models. The economic feasibility must be there. Wholesale change-out of field devices is difficult if not impossible to justify because of the life remaining value of most of the field devices.

Utilities and Manufacturers need an architecture and compliance model allowing the Utilities to build their Grids piecemeal and allowing the individual Utility Grids to naturally grow and connect together as the millions of distribution field devices and tens of thousands of transmission substation and tie station devices are changed out with SmartGrid certified devices.

The devices and data networks of tomorrow must be better equipped for the low latency and other stringent QoS properties required to sense anomalies over the entire span of all connected and inter-dependant Utility Grids [Bak09b]. Grid control centers of today receive data approximately two seconds after catastrophic events which is often too late for avoidance of system instability and ultimately cascaded system segment blackouts.

Manufacturers are becoming aware of the need for better information availability, but are being drawn toward "Off the shelf Internet technologies and networks such as web services". As Ken Birman from Cornell University has warned [Bir06],

> "We're poised to put air-traffic control, banking, military command-and-control, electronic medical records, and other vital systems into the hands of a profoundly insecure, untrustworthy platform cobbled together from complex legacy software components".

As he and other computer scientists have warned, the Internet is inherently too slow, unpredictable and unsecure for the future SmartGrid data sensing and control at the most sensitive needs for low latency. Also, the inflexibility of today's communications networks does not manage the different latency and other QoS needs for various system data. Guaranteed latency and predictability through a "Quality of Service" (QoS) function that is suitable for fast wide-area protection and control is paramount. Another looming challenge is the overwhelming scale of instrumentation at hundreds of thousands of locations for fault diagnosis needed to occur automatically and in real time while being secured against intrusion or terrorist attack to determine the fundamental science of collecting management information or proper replication for such a large magnitude. Again, Birman notes [Bir06]:

> "Our inability to solve the large-scale problem is due to market forces. Vendors are reluctant because customers are not demanding solutions and DARPA, NSF and other agencies are also reluctant to fund because these types of investments of research may not translate directly into better solutions. Without backing to explore robustness issues, researchers have moved to greener pastures".

Again, the Utilities and Manufacturers desperately need a well described road map for their communications systems upgrading and device products planning respectively. It is a crucial requirement that this includes a well-considered architecture for data delivery services — not just low-level protocols cobbled together in arbitrary combinations — that spans generation, transmission and distribution, as well as likely future monitoring by NERC and possibly also DHS. Without this systematic foundation of communications ease across the Grid, the intelligence desired for the ultimate SmartGrid will be unwieldy and difficult if not impossible to achieve. In this case, the "smart" grid will end up being rather "dumb", at great cost to society.

The costs of this "dumb grid" will be very large. According to the Galvan Institute, interruptions in our power supply costs the US an estimated $150 billion a year [Gal09]. If the data delivery situation is not radically improved, this number will likely go up dramatically. The grid is being operated closer to its safety margins each year, not enough transmission lines are being built, and now new kinds of power such as wind and solar and other distributed generation resources are being added without adequate monitoring services. These are all strongly destabilizing trends. Indeed, the US Dept of Energy recognized that these integration issues are among "key infrastructure issues" [DOE08b].

Today's "Not So Smart" Grid

The limited capabilities of the present power grid's communication system in turn limit the kinds of protection and control that can be done [HBB05, TBV+05]. With the exception of the initial power equipment problems in the renowned August 14, 2003 blackout, the on-going and cascading failures were almost exclusively due to problems in providing the right information to the right place within the right time [Cle07]. The failure providing reliable real-time data is the root cause of major blackouts [AF06]. The communications being spoken of here are limited to the Grid Operation Centers of which the data sensors are providing data from the generation transmission ties and substations only.

Presently, the small latency (<2msec) needed for Grid Reliability actions is woefully accommodated. Typically two or more seconds have elapsed before the Grid Operator sees the event which may have already produced irreversible system instability for a system blackout.

The aforementioned crippling blackouts precipitated governmental activity to remedy such vulnerability of the North American power grid. A statement of work to deliver a North American SynchroPhasor Initiative Network (NASPInet) to the Department of Energy (DOE) National Energy Technology Laboratory (NETL) was submitted in May of 2008. The description of the NASPInet components and operational requirements are detailed in this document [DOE08a].

Consider also, that communications availability to the remaining portions of the power grid could be important to reliability. Reduction of consumer loads could effectively act as a strategically placed generator of the proper size to re-establish stability. Beyond reliability issues, many other economical enterprises are enabled with the entire grid's set of devices able to communicate with each other, of course, with the limitations of security and "Need to know" permission.

The Grid of today is splintered and isolated with many proprietary systems. These proprietary systems may be vying to be the de-facto methodology in a particular domain or simply may enjoy the single supplier environment. There are also communication networks and devices that have attempted to provide interoperability with available standards, but have failed because of the lack of a uniform third party compliance entity for certification to insure interoperability.

As seen in Figure 1. "Today's Not So SmartGrid Architecture" starting on Home/Commercial Area Networks (HAN/CANnets), the connectivity between the emerging Home Area Networks (HANs) and the Utility Distribution Network (DistributionNet) is through the Utility meter. Unless the meter provides a standard communications interface for the any/many HANs to mate to, this will be a limitation as well as an expensive bottleneck. The zeal of the meter manufacturers to develop various HAN interfaces within their meters will likely be viewed as a premature miss step that must be reversed [WACKS02]. In order to create and maintain an effective method of communicating demand/response data to/from customer loads and distributed resources, the Utilities must provide standard interface modules to both meters and to the residential/commercial owners' HAN/CAN energy management automation controllers [WACKS02]. The comm. modules interfacing from meters to the DistributionNet and from the home/commercial energy management automation controllers' to the DistributionNet interfaces should be the same, however, the meters and energy management automation controllers (EMAC)s should be interfaced by the comm. modules to the DistributionNet independently.

Let's assume that there may be more than one Home Area Network (HAN) competing communications technologies. The meter manufacturer will be placed in the predicament of dealing with all of the commercially available HANs. There are over 30 known HANs in existence today. Ultimately, the utility pays for all of this development work for multiple home area networks and commercial/industrial area networks via each of the meter manufacturers' devices that are purchased. Beyond the multiple efforts of the utility metering manufacturers, look at what the home appliance manufacturers are faced with. Must they also provide multiple interfaces to the various HANs and CANs ? What about the Distributed Resources? If the Utility and consumer have an interest in a contract for the delivery of the Distributed Resource to the Grid, does the Distributed Resource manufacturer provide multiple interfaces to accommodate each of the HANs or CANs?

The special case of the Electric Vehicle (EV) being mobile and receiving energy, but sometimes providing energy to the grid screams loudly of the need to interface to the Utility and be regarded as a mobile meter with an address. Multiple interfaces for the EV to various home and commercial area networks will be very confusing to the car manufacturers. Although the initial response may indicate a preference of the EV to just plug into wherever it is with no billing communications, providing power and communications interface guidance now will allow opportunities to emerge without confusing limitations. This is also true with any devices expected to interface with HANs and CANs. Any device forecast that indicates potential need to communicate with the Utility for Demand Response must have the guidance of interface requirements.

In Figure 1, existing Demand curtailment systems exist and work satisfactorily for load reduction, however, these systems are typically proprietary and isolated. The end-device-disconnect modules at the consumers' homes or businesses are typically hardwired to the hot water heater or other appliance or load to be curtailed. The curtailment is typically isolated from the emerging energy management systems within the home or commercial establishment.

Distribution Automation is not immune to today's isolated system identity. These systems for distribution line equipment automation work satisfactorily; however, these systems are also typically proprietary and isolated.

Utility SCADA systems in the US do use a standard communications protocol, Distributed Network Protocol (DNP3) over TCP/IP. It is maintained by the DNP users group who provide test procedures to certification companies resulting in a very desirable environment of interoperability. DNP3 is a simple protocol with very efficient use of bandwidth and it is very reliable [EPRI 05]. In today's Grid, DNP3 is a bright spot for these reasons. Unfortunately, tomorrow's grid will need more from the substation domain's communication. Beyond the need for a lower latency in the gathering of data, the data will be necessarily shared between other domains. The simple point list oriented data of DNP3 is adequate for the single domain operation, however, it will be unmanageable with the required detailed mapping of its information to be shared between domains. The latency of approximately two seconds will have to be reduced to approximately 2- 4 milliseconds within the substation. DNP3 is very compact, but its large latency is due mainly to the need to poll information repeatedly from a single master. Also, DNP3 utilizes TCP/IP as the lower communication layers and is limited to the internet static properties, operational practices, performance characteristics and load characteristics [BHG+07]. It is not just cyber-security that is a problem with TCP/IP. Computer science researchers have long understood that "Off the shelf Internet technologies and networks such as web services" while "reliable" and quite useful for general purpose web applications, is inadequate for many mission-critical wide-area applications, because it has narrow coverage of failures and a high and unpredictable latency [BHG+07]. For a recent study, see [BCH+05]. For these reasons, DNP3 may be forced into displacement to provide the necessarily small latency for the SmartGrid and manageable data. DNP3 as supported by its users group has been a model for interoperability in the US and hopefully this same group can adjust and support the next communications protocol capable of the 2 – 4 mSec latency requirements within the substations. This future set of requirements is accommodated in the TC57 standards of IEC 61850 in conjunction with IEC 61970 and IEC 61968. These standards are recommended for the transmission partition for substations, tie stations and generation plants with modifications to match the QoS requirements of the NASPInet data highway.

Inadequacy of Standard Internet Protocols

The question often arises, "Why not just use the internet's common protocols such as TCP and UDP to implement power system monitoring and control applications within the transmission substations, tie stations, generators and control operations?". The answer requires understanding of the major differences in the operating context and required characteristics of the Internet and an Electric Power Information Network (EPInet) such as NASPInet/GridStat [BHG09]:

1. Static properties,
2. Operational practices,
3. Performance characteristics and
4. Load characteristics.

Of the static attributes, the Internet has approximately one billion hosts and it forwards, on demand, data from any one of them to any other. This contrasts with the requirements and properties of an Electric Power Internet (EPInet) such as the emerging NASPInet, with an EPInet hosting several orders of magnitude less. An EPInet design yields high quality delivery to a known set of customers for a known set of applications that are slowly changing [BHG09]. Operational practices differ in admission control and the frequency and control of topology changes. Because all comers are welcome to the Internet, new hosts can be added with the IP backbones expected to provide at a minimum "Best effort" delivery for each and every packet. EPInets have admission control perimeters which control both addition of new equipment and acceptance of packet traffic. The traffic control is essential to providing real time service. The internet router configurations can be changed without warning leading to changes in paths taken by data. Also, there is no single location that knows more than a tiny fraction of the network topology. The data just gets forwarded towards its destination at each router according to that router's current knowledge of the topology. Thus, Internet routing algorithms are subject to short term instability when links or routers fail or are reconfigured. This is unacceptable for an EPInet. Topology changes for an EPInet are to be coordinated previous to operation to ensure QoS requirements continue to be met [BHG09]. The service and performance characteristics between the EPInet and Internet rest mainly with the ability of EPInet to maintain a level of predictability for the real time applications. EPInets limit their traffic load using admission control. Packet loss is resolved by multiple disjoint paths for each periodically updated variable (PUV).

The Internet also lacks admission control, thus, the lack of predictability of service. The Internet rarely makes the latency deadline when a packet is dropped. Recently proposed transport protocol design for the Internet, such as SCTP [OY02] and DCCP [KHF06] attempt to address some of the shortcomings of the Internet's main transport protocols, TCP and UDP, however, all work under the constraints of traffic detection. Real time traffic of an EPInet requires reserved bandwidth and congestion avoidance rather than congestion detection utilized by Internet protocols [BHG09]. The Internet design for its data and the EPInet design for its intended data illustrate the general versus a specific set of capabilities respectively. The data traffic carried on the Internet is unconstrained by design. The data traffic carried on the EPInet is very constrained which in turn allows EPInets to meet QoS requirements that are beyond reach in the Internet. In particular, the power grid sensors called synchrophasors or phasor measurement units (PMUs) have GPS accurate clocks and produce 30 – 250 updates per second. The care of preserving the precise global snapshots of the PMUs is a design requirement in the EPInets [BHG09].

Tomorrow's SmartGrid

As opposed to the disarray of systems in "Today's Not So SmartGrid", "Tomorrow's SmartGrid" will:

1. Consolidate functions within the natural partitions
2. Utilize standardized interfaces for devices
3. Utilize standardized communications protocols for data sensor devices
4. Utilize enterprise application standards
5. Implement a low latency Data Bus and Management Bus system for the substation, generation, transmission tie stations utilizing publish-subscribe data delivery service and stringent QoS advocated via GridStat [BHG+07]
6. Implement one or more communication standards over-sight committee(s) to insure proper and uniform compliance and certification of data sensor end devices, communications bridges, other communications network(s) devices and applications.

In Figure 2 and Figure 5, "Tomorrow's SmartGrid" architecture, and "Tomorrow's Utility DistributionNet", it is seen that there is now proposed only one "Utility DistributionNet". This communications net for Distribution may consist of multiple vendor networks; however, they all utilize their networks to deliver the same payload. The payload is the ANSI C12.19 data with C12.22 rewrite attributes of addressability for the upstream C12.22 communications relays and C12.22 master relay of that system.

It can also be seen in Figure 3, that a standardized Home Area Network (HAN) based upon the work of UCA/Utility AMI/Open HAN Architecture [ESC07] utilizing the ANSI C12.22/C12.19 to HAN comm. module interface streamlines all connectivity to the HAN as well as any appliance device possibly collaborated between the home owner and the Utility. It is noted here that the Consumer Appliance Manufacturers should determine only one interface for their appliances that all HANs should design to. The IEEE 1547 Standard addresses the connectivity issues of Distributed Resources even at the HAN and Distribution voltages. The utility meters, HAN energy management automation controllers (EMAC)s i.e., Zigbee EMACs, CAN EMACs, i.e., BACnet EMACs and other end devices such as Distribution Automation devices are interfaced to the DistributionNet with the same Distribution network communications modules (ANSI C12.22).

The HAN/CAN Energy Management Automation Controller (EMAC) should interface to the Utility DistributionNet via a C12.22 interface in the form of a communications module (C12.22 Comm. Module) provided by the Utility [WACKS01]. Therefore, the Utility using this standardized scheme can have interoperable DistributionNet devices by requiring the ANSI C12.22 interface. Remarkably, the ANSI C12.22 interface standard was originally developed to allow huge populations of utility meters communication independence from communications systems. This immunity allows failed or obsolescent communication system(s) to come and go without disturbing the meter (or End Device) population. Communications capability within the meters subject the meters to the risk of being obsolescent due to any problems of a communications system. The C12.22 Comm. Module was intended to mate to any meter with an ANSI C12.22 interface. An ANSI/IEEE/Measurement Canada joint Standards subcommittee working group has been organized to produce the physical attributes of communication modules utilizing the existing ANSI C12.22 communications standard. As its intention to be an interface protocol to networks, it is applicable to the challenges SmartGrid has especially with DistributionNet devices and HAN/CAN devices that need to tunnel metering or command data between the Utility DistributionNet and any of the home or commercial appliances, loads, or generation.

Figure 3, Tomorrow's Home Area Network/Commercial Area Network, illustrates how the multiple and isolated distribution load control functions may be consolidated and provide further flexibility within the HANs and CANs. With a standard interface for the appliances, distributed generation, and EVs, any HAN or CAN may be chosen by the consumer and still be fully flexible with any future collaboration with the Utility via Demand Response contracts and/or rate schedule riders. EVs equipped with the North American communications standards for metering and distribution end devices will be able to provide standard metering data wherever it may be located. EV location may be determined by it's C12.19/C12.22 registration action when attached to any HAN or CAN via the HAN or CAN EMAC/C12.22 comm. module. The cell phone industry has blazed the path for Utilities to accept billing data on a mobile basis. Albeit, the Utilities will certainly be anxious and slow to implement such a program, the EV preparedness with a C12.19/C12.22 on board meter will keep all the options open.

Figure 2 shows how the multiple distribution enterprise systems may be consolidated utilizing the singular Communication Protocol ANSI C12.19 to communicate the proper data/control for all of the distribution enterprise systems. Also, it is seen that the enterprise systems are further consolidated by utilizing IEC 61970/61968 to standardize the data packages for enterprise sharing.

For the Rural Electrification Authority (REA) and other Utilities enjoying “Multi-Speak”, it is proposed that there be a semantic bridge developed between IEC 61970/61968 to increase Distribution Enterprise homogeneity of all utilities in North America [NRECA07]. This may become important when the Publish/Subscribe middleware, NASPInet Data Bus, GridStat, is implemented for the low latency times required on the Substation, Transmission, Generation, ISO partition.

Figure 4 shows the SCADA utilizing IEC 61850/61970. It will become necessary for the lower communications layers to be upgraded to accommodate the NASPInet – GridStat interface as well as the expected IEEE 1646 lower latency requirements of 2 – 4 mSec within the substations. Also, in Figure 4 it is noted that the IEEE 1547.5 standard gives guidance for the Grid connectivity of 10 MVA Distributed Resources. Within Figure 4 is a pictorial of the (NASPInet) in terms of GridStat [BHG+07]. The complexity of the data paths has been simplified in that there is one data plane and one management plane to route the data with the proper and assured latency required of each subscriber.

The key data sensors are the Phasor Measurement Unit (PMUs; also known as synchrophasors). The NASPI work has determined that the angular displacement discovered between a normal operation and a non-planned interruption of a large load or generator produces a signature which can be recognized from a library of signatures of angular separation data calculated by mesh analysis techniques prior to the event. The potentially catastrophic interruption or fault can be compensated automatically and much faster than human intervention. A recent (and striking) example of this was where PMUs were used to successfully identify and then manage islanding during Hurricane Gustav [GMT08]. This was done with only 21 PMUs deployed across a four-state area (far more than all but a few places in the country have, but far less than many hope will be deployed in the eastern grid soon) and prevented large blackouts. This is a stellar example of what could readily be called a “smart transmission grid”.

With the critical need for low latency of this phasor data from all strategic locations over the Grid and synchronized with GPS technologies, the NASPInet has been carefully designed to accomplish this extremely fast data collection and control. With the NASPInet superhighway for extremely critical low latency data, it makes for an opportunity to utilize this data bus for connectivity across the Grid [Bak09a]. It is shown that the Distribution Enterprise Applications block are connected to the Data Bus via the GridStat “Publish/Subscribe” mechanisms managed by the Quality of Service (QoS) plane. Among other tasks, the QoS assures the latency of the data connections be met, but not exceeded to the detriment of the Data Bus.

There are no other communications architectures known to date that are capable of managing the extremely low latency data flow as efficiently as the NASPInet, GridStat prototype, however, there are attributes of success of other protocol architectures such as the OPC-UA (Open Connectivity-Unified Architecture) that should be considered for the sake of interoperability seen especially with the compliance model incorporated. OPC-UA is an industrial effort and widely deployed open technology to provide interoperability for data collection and control. It was developed for industrial automation and the enterprise systems that support industry and the OPC-UA is described in a layered set of specifications broken into Parts. It is purposely described in abstract terms and in later parts married to existing technology on which software can be built. This layering is on purpose and helps isolate changes in OPC-UA from changes in the technology used to implement it. Indeed, a NASPInet Data Bus instance such as GridStat could be used to delivery different message formats from existing standards, with the translation to and from the protocols (such as IEC 61850’s GOOSE messages, designed now for just within a substation) being done at the “edges” of this Data Bus (so as not to slow it down).

The NASPInet technology GridStat is designed specifically for the SmartGrid. In this architecture, Utility Grid Operations may communicate to any distribution substation or any grouping of consumer loads for emergency load reduction utilizing the GridStat connectivity to the consolidated Distribution

Enterprise Applications. The GridStat support applications should be produced in a uniform manner for SmartGrid utilization across the extents of the Grid.

The requirements for the data delivery services for smart grids, as outlined in [Bak09b, BHG09], seem doable with focused effort, not decades of far-off research. Many technologies developed by the military (for example, DARPA) can probably be brought to bear on this problem [Sch09]. However, this would take a focused effort; if smart grid data delivery evolves like things have in the last few decades, there is little hope that most of the dreams of the smart grid will be realized.

SUMMARY

To use a metaphor, the durable and ultimately the successful construction of any building or structure is directly dependant upon the accurate and well built foundation started only after a well thought out architectural plan is drawn. The SmartGrid is no different. Before any meaningful applications can be produced without serious miss-steps, the foundation and architecture of communications must be determined through:

1. Proper architecture
2. Utilization of Electric Industry produced standards created through recognized standards bodies, thus, produced through consensus of the Industry.
3. A well defined and organized committee(s) to oversee the conformance of the SmartGrid "End devices" to the chosen Standard communications protocols to produce the elusive interoperability and ease of communications necessary for the SmartGrid success.

The attributes of success in the DNP3 users group, efforts of UCA/Utility AMI Open HAN Task Force, NRECA, GridWise Architecture Council, NASPI, EPRI IntelliGrid, Grid-Interop, NEMA, NIST, FERC and the IEEE, ANSI &MC Object ID Oversight Committee should be condensed to embody the above three foundation requirements. This paper is an attempt to coalesce the architectures and vast knowledge of the above organizations to create a simple starting point for the SmartGrid.

In the distant future, the concepts of the NASPInet Data Bus (e.g., GridStat) QoS may migrate into the distribution and HAN/CAN communications if the need for managing latency and other QoS requirements in these partitions is found to be beneficial [Bak09a]. However, for the quickly approaching tomorrow, our SmartGrid outfitted with a strong communications foundation will alleviate North America's Electric Industry's pressing needs as well as provide many economic opportunities.

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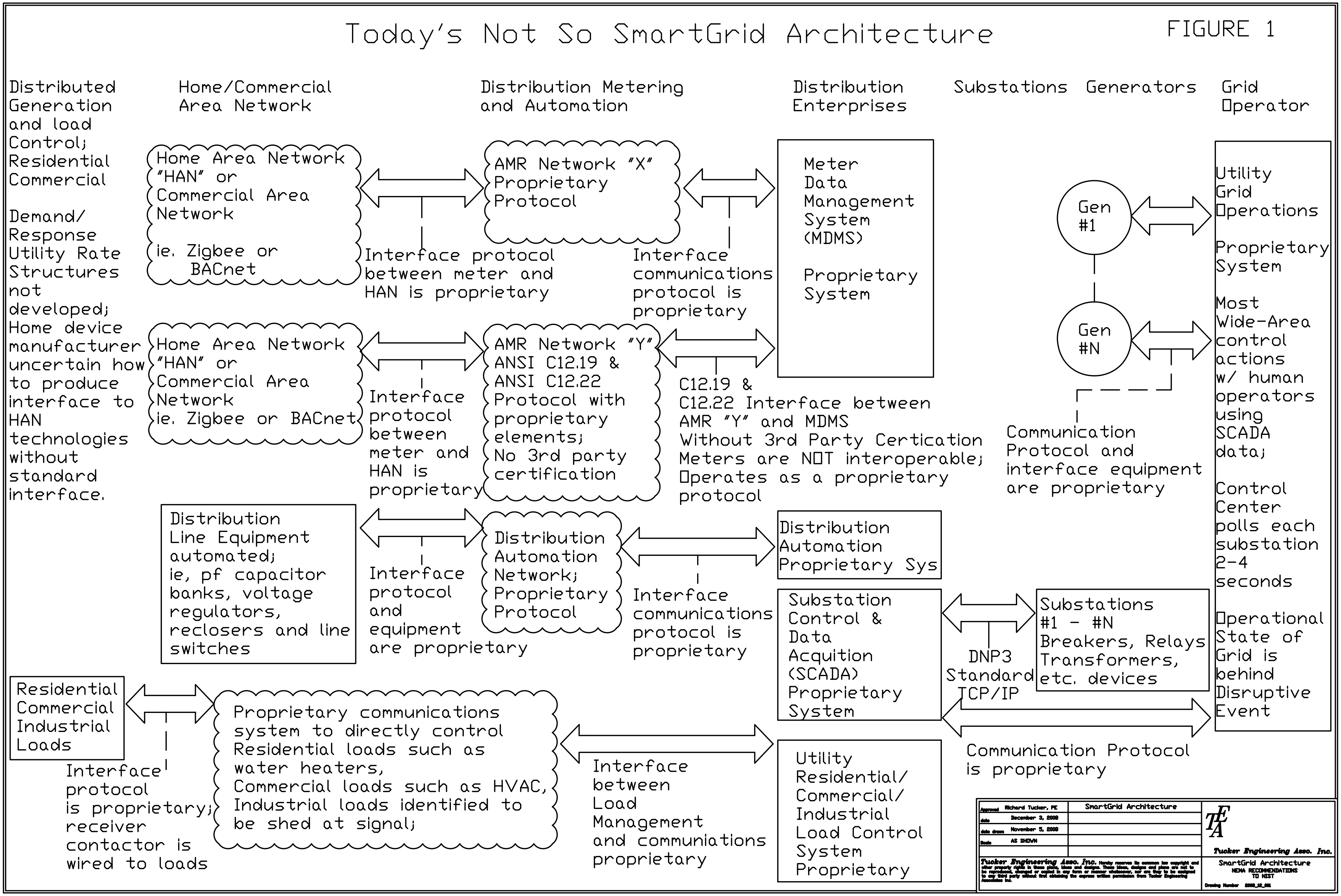
Today's Not So SmartGrid Architecture
FIGURE 1
Distributed Generation and load Control; Residential Commercial
Demand/ Response Utility Rate Structures not developed; Home device manufacturer uncertain how to produce interface to HAN technologies without standard interface.
Home/Commercial Area Network
Distribution Metering and Automation
Distribution Enterprises
Substations
Generators
Grid Operator
Home Area Network "HAN" or Commercial Area Network
ie. Zigbee or BACnet
Interface protocol between meter and HAN is proprietary
AMR Network "X" Proprietary Protocol
Interface communications protocol is proprietary
Meter Data Management System (MDMS)
Proprietary System
Gen #1
Gen #N
Utility Grid Operations
Proprietary System
Most Wide-Area control actions w/ human operators using SCADA data;
Control Center polls each substation 2-4 seconds
Operational State of Grid is behind Disruptive Event
Home Area Network "HAN" or Commercial Area Network ie. Zigbee or BACnet
Interface protocol between meter and HAN is proprietary
AMR Network "Y" ANSI C12.19 & ANSI C12.22 Protocol with proprietary elements; No 3rd party certification
C12.19 & C12.22 Interface between AMR "Y" and MDMS Without 3rd Party Certication Meters are NOT interoperable; Operates as a proprietary protocol
Communication Protocol and interface equipment are proprietary
Distribution Line Equipment automated; ie, pf capacitor banks, voltage regulators, reclosers and line switches
Interface protocol and equipment are proprietary
Distribution Automation Network; Proprietary Protocol
Interface communications protocol is proprietary
Distribution Automation Proprietary Sys
Substation Control & Data Acquition (SCADA) Proprietary System
DNP3 Standard TCP/IP
Substations #1 - #N Breakers, Relays Transformers, etc. devices
Communication Protocol is proprietary
Residential Commercial Industrial Loads
Interface protocol is proprietary; receiver contactor is wired to loads
Proprietary communications system to directly control Residential loads such as water heaters, Commercial loads such as HVAC, Industrial loads identified to be shed at signal;
Interface between Load Management and communiations proprietary
Utility Residential/ Commercial/ Industrial Load Control System Proprietary
Approved Richard Tucker, PE
date December 3, 2008
date drawn November 5, 2008
Scale AS SHOWN
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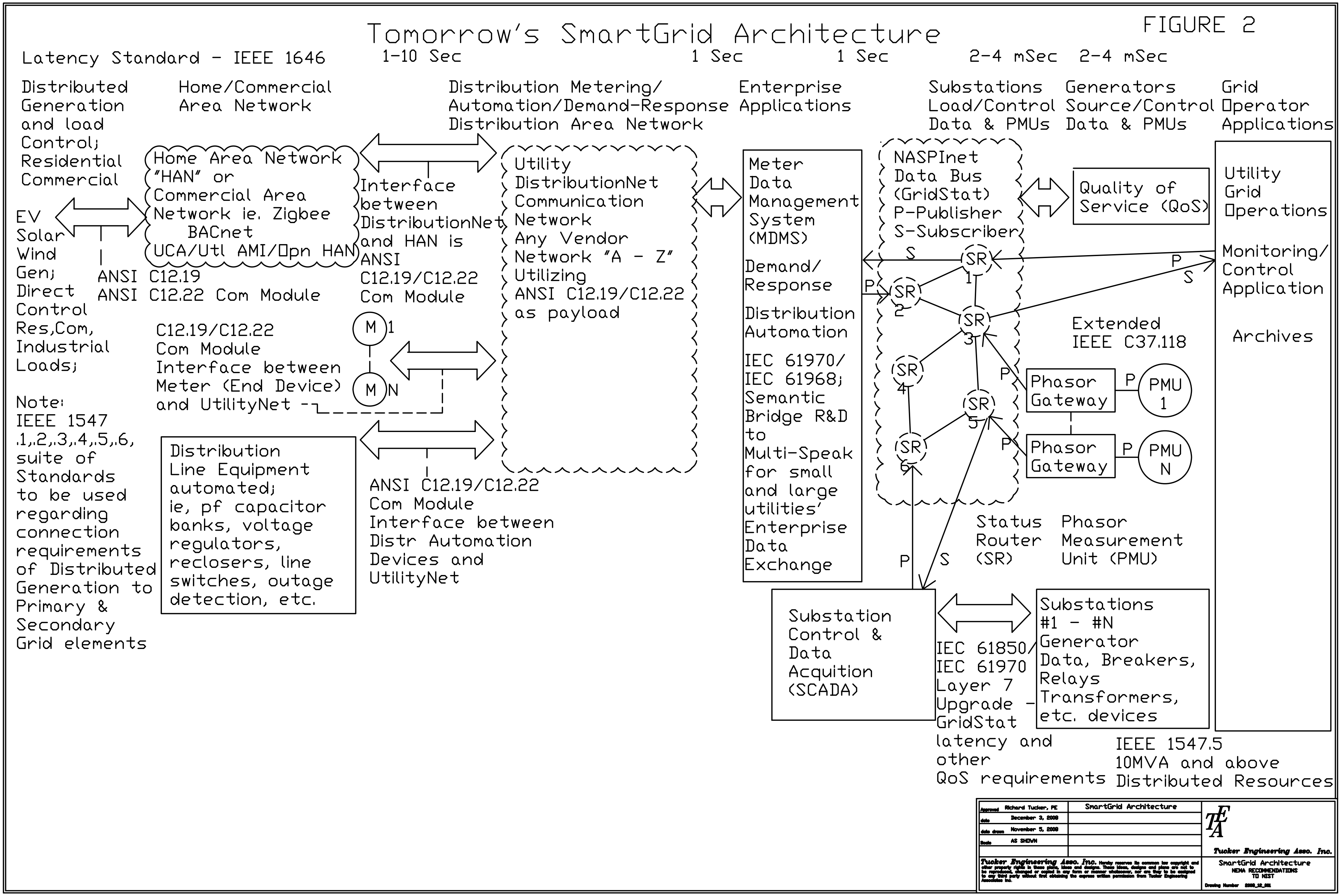

Tomorrow's SmartGrid Architecture
FIGURE 2
Latency Standard - IEEE 1646
1-10 Sec
1 Sec
1 Sec
2-4 mSec
2-4 mSec
Distributed Generation and load Control; Residential Commercial
Home/Commercial Area Network
Distribution Metering/ Automation/Demand-Response Distribution Area Network
Enterprise Applications
Substations Load/Control Data & PMUs
Generators Source/Control Data & PMUs
Grid Operator Applications
EV Solar Wind Gen; Direct Control Res,Com, Industrial Loads;
Note: IEEE 1547 .1,.2,.3,.4,.5,.6, suite of Standards to be used regarding connection requirements of Distributed Generation to Primary & Secondary Grid elements
Home Area Network "HAN" or Commercial Area Network ie. Zigbee BACnet UCA/Utl AMI/Opn HAN
ANSI C12.19
ANSI C12.22 Com Module
C12.19/C12.22 Com Module Interface between Meter (End Device) and UtilityNet
M 1
M N
Interface between DistributionNet and HAN is ANSI C12.19/C12.22 Com Module
Utility DistributionNet Communication Network Any Vendor Network "A - Z" Utilizing ANSI C12.19/C12.22 as payload
Distribution Line Equipment automated; ie, pf capacitor banks, voltage regulators, reclosers, line switches, outage detection, etc.
ANSI C12.19/C12.22 Com Module Interface between Distr Automation Devices and UtilityNet
Meter Data Management System (MDMS)
Demand/ Response
Distribution Automation
IEC 61970/ IEC 61968; Semantic Bridge R&D to Multi-Speak for small and large utilities' Enterprise Data Exchange
NASPInet Data Bus (GridStat) P-Publisher S-Subscriber
SR 1
SR 2
SR 3
SR 4
SR 5
SR 6
P
S
Quality of Service (QoS)
Utility Grid Operations
Monitoring/ Control Application
Archives
Extended IEEE C37.118
Phasor Gateway
PMU 1
PMU N
Status Router (SR)
Phasor Measurement Unit (PMU)
Substation Control & Data Acquition (SCADA)
IEC 61850/ IEC 61970 Layer 7 Upgrade - GridStat latency and other QoS requirements
Substations #1 - #N Generator Data, Breakers, Relays Transformers, etc. devices
IEEE 1547.5 10MVA and above Distributed Resources
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date December 3, 2008
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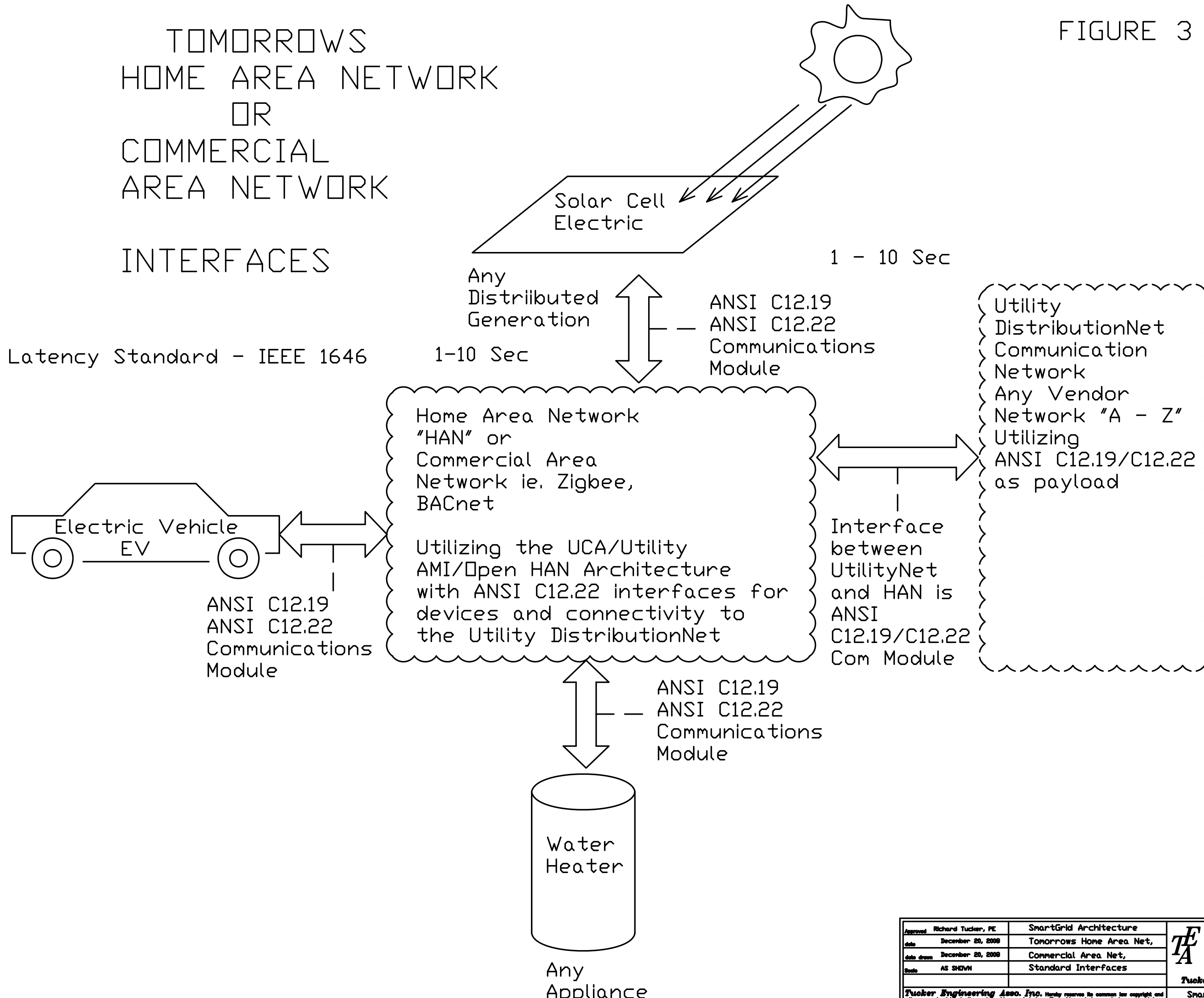
FIGURE 3

TOMORROWS HOME AREA NETWORK OR COMMERCIAL AREA NETWORK

INTERFACES



IEEE 1547 .1,.2,.3,.4,.5,.6, suite of Standards to be used regarding connection requirements of Distributed Generation to Primary & Secondary Grid elements

Approved Richard Tucker, PE	SmartGrid Architecture	TEA
date December 20, 2008	Tomorrows Home Area Net,	
date drawn December 20, 2008	Commercial Area Net,	
Scale AS SHOWN	Standard Interfaces	Tucker Engineering Asso. Inc.

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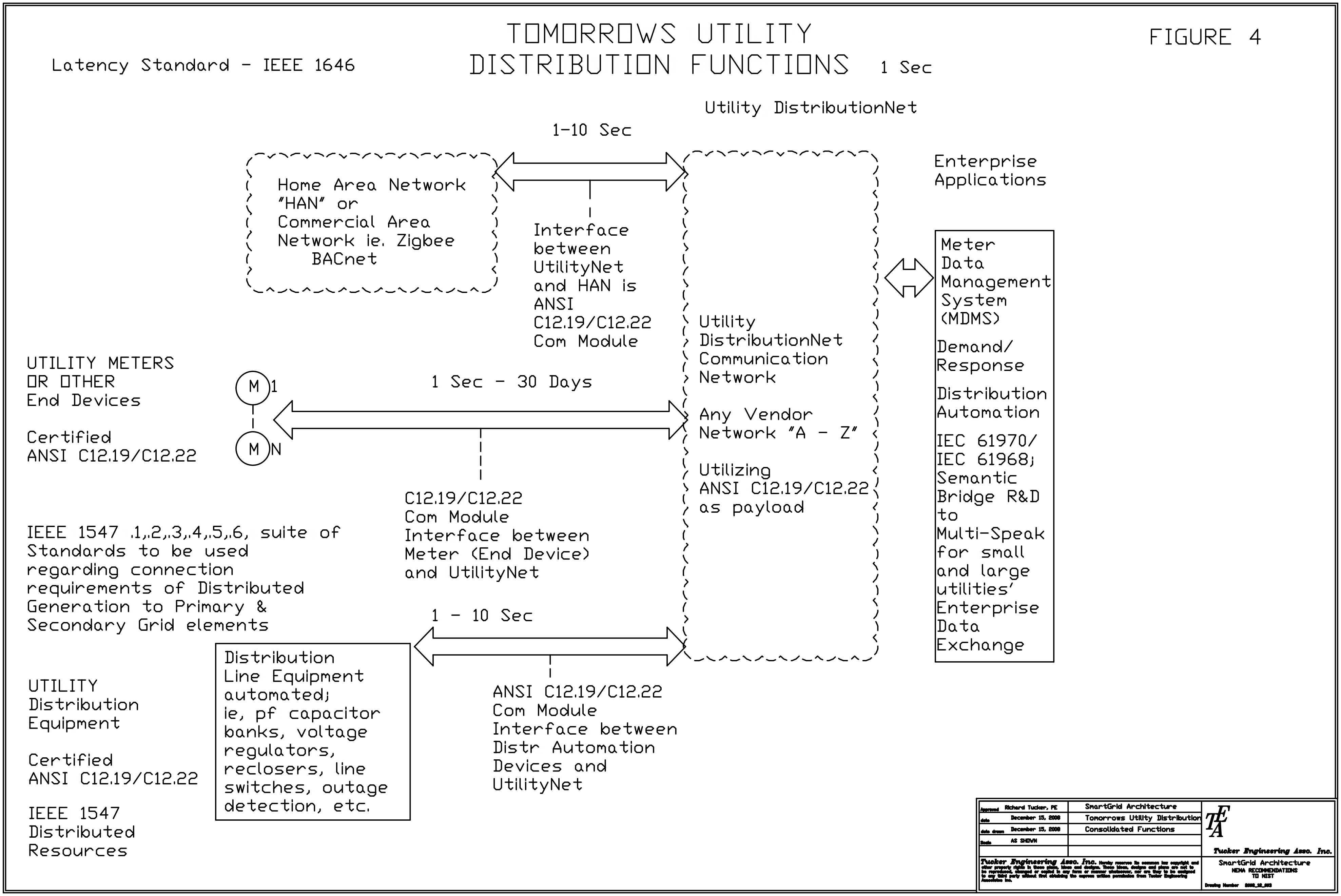
TOMORROWS UTILITY
DISTRIBUTION FUNCTIONS
FIGURE 4
Latency Standard - IEEE 1646
1 Sec
Utility DistributionNet
1-10 Sec
Home Area Network "HAN" or Commercial Area Network ie. Zigbee BACnet
Interface between UtilityNet and HAN is ANSI C12.19/C12.22 Com Module
Enterprise Applications
Meter Data Management System (MDMS)
Demand/ Response
Distribution Automation
IEC 61970/ IEC 61968; Semantic Bridge R&D to Multi-Speak for small and large utilities' Enterprise Data Exchange
UTILITY METERS OR OTHER End Devices
Certified ANSI C12.19/C12.22
M 1
M N
1 Sec - 30 Days
Utility DistributionNet Communication Network
Any Vendor Network "A - Z"
Utilizing ANSI C12.19/C12.22 as payload
C12.19/C12.22 Com Module Interface between Meter (End Device) and UtilityNet
IEEE 1547 .1,.2,.3,.4,.5,.6, suite of Standards to be used regarding connection requirements of Distributed Generation to Primary & Secondary Grid elements
1 - 10 Sec
UTILITY Distribution Equipment
Certified ANSI C12.19/C12.22
IEEE 1547 Distributed Resources
Distribution Line Equipment automated; ie, pf capacitor banks, voltage regulators, reclosers, line switches, outage detection, etc.
ANSI C12.19/C12.22 Com Module Interface between Distr Automation Devices and UtilityNet
Approved Richard Tucker, PE
date December 15, 2008
date drawn December 15, 2008
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SmartGrid Architecture
Tomorrows Utility Distribution
Consolidated Functions
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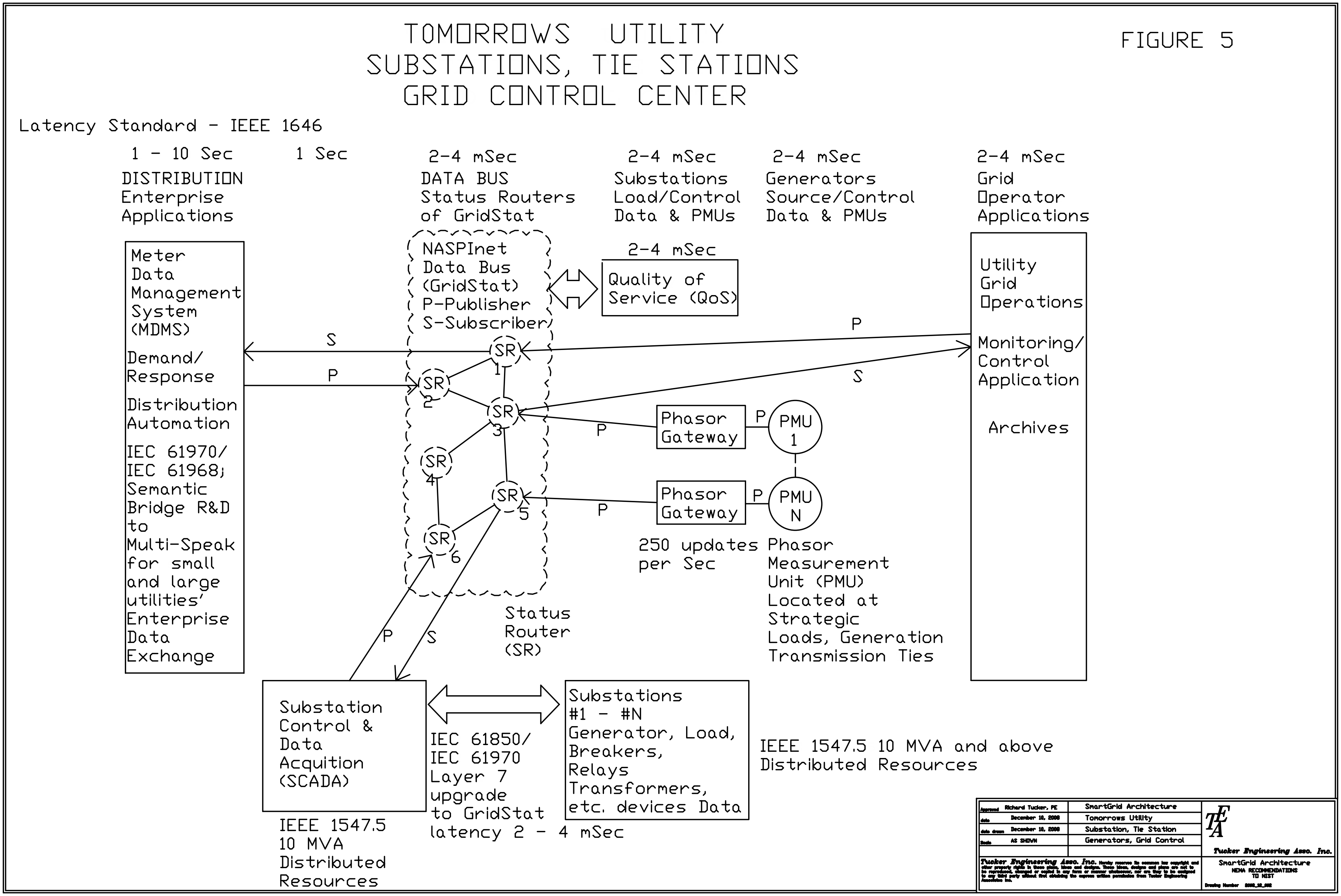
TOMORROWS UTILITY
SUBSTATIONS, TIE STATIONS
GRID CONTROL CENTER
FIGURE 5
Latency Standard - IEEE 1646
1 - 10 Sec
1 Sec
2-4 mSec
2-4 mSec
2-4 mSec
2-4 mSec
DISTRIBUTION Enterprise Applications
DATA BUS Status Routers of GridStat
Substations Load/Control Data & PMUs
Generators Source/Control Data & PMUs
Grid Operator Applications
Meter Data Management System (MDMS)
Demand/ Response
Distribution Automation
IEC 61970/ IEC 61968; Semantic Bridge R&D to Multi-Speak for small and large utilities' Enterprise Data Exchange
NASPInet Data Bus (GridStat) P-Publisher S-Subscriber
2-4 mSec
Quality of Service (QoS)
Utility Grid Operations
Monitoring/ Control Application
Archives
S
P
P
S
SR 1
SR 2
SR 3
SR 4
SR 5
SR 6
Phasor Gateway
P
PMU 1
P
Phasor Gateway
P
PMU N
P
250 updates per Sec
Phasor Measurement Unit (PMU) Located at Strategic Loads, Generation Transmission Ties
Status Router (SR)
P
S
Substation Control & Data Acquition (SCADA)
IEC 61850/ IEC 61970 Layer 7 upgrade to GridStat latency 2 - 4 mSec
Substations #1 - #N Generator, Load, Breakers, Relays Transformers, etc. devices Data
IEEE 1547.5 10 MVA and above Distributed Resources
IEEE 1547.5 10 MVA Distributed Resources
Approved Richard Tucker, PE
date December 10, 2008
date drawn December 10, 2008
Scale AS SHOWN
SmartGrid Architecture
Tomorrows Utility
Substation, Tie Station
Generators, Grid Control
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