Mesh Smart Metering Communication Infrastructure

Technical Overview Document

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1. Executive Summary

This document provides a technical overview of the mesh smart metering communication infrastructure designed to enable reliable communication between a Head-End System (HES) and electricity meters within a defined geographic area. The infrastructure employs a self-organizing mesh network topology with automatic failover capabilities to ensure continuous operation. Communication is managed through the EMOG Protocol (Encrypted, Mesh, Own-Generation), which provides secure, reliable, and self-healing communication across the network.

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2. System Purpose and Scope

2.1 Primary Objectives

The mesh smart metering communication infrastructure provides:

- **Meter Communication**: Bidirectional communication between the HES and electricity meters within a specific geographic area
- **User Interface**: Communication between consumer keypads and their associated meters
- **Network Resilience**: Automatic network reconfiguration in the event of gateway failures
- **Scalability**: Support for deployments ranging from small installations to large-scale networks
- **Own-Generation Support**: Specialized metering for sites with backup generators or alternative power sources
- **Offline Token Delivery**: Support for prepaid metering without continuous HES connectivity

2.2 Typical Deployment Scenarios

The infrastructure is designed for the following deployment contexts:

- Sub-metering installations behind bulk metering supply points
- Complete transformer supply areas in electricity distribution networks
- Apartment blocks with own-generation (backup generator) capabilities
- Mixed deployments with standard meters, generator-monitored installations, and solar rooftop installations

- Prepaid metering installations with offline token delivery capability

2.3 Document Scope

This document covers the communication infrastructure components and network topology. The Head-End System (HES) is outside the scope of this document. Detailed keypad user operation is covered in a separate user manual. Detailed protocol specifications are provided in the appendices.

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3. System Architecture Overview

3.1 Network Components

The mesh infrastructure consists of the following key components:

3.1.1 Gateways

- Provide the interface between the mesh network and external systems (HES)
- Assigned to Level 0 in the network hierarchy
- Multiple gateways can coexist in a single mesh deployment
- Nodes automatically associate with available gateways
- Gateway failure triggers automatic network reconfiguration
- Can operate without continuous HES connection for prepaid-only installations

3.1.2 Meter-Nodes

- Primary routing and relay devices in the mesh network
- Each meter-node can communicate with up to 100 meters
- Typical deployment: approximately 50 meter-nodes per mesh
- Participate in mesh routing and data aggregation
- Assigned to levels 1, 2, 3, etc. based on distance from gateway
- Maintain parent-child relationships for efficient routing

3.1.3 Keypads

- User interface devices for both prepaid and smart meters
- Function as nodes within the mesh network with their own levels
- Communicate with gateway, which routes messages to meters via meter-nodes
- Do not communicate directly with meters
- Allow consumers to interact with their electricity meters

- Support offline STS token entry when HES connection unavailable
- Typical deployment: approximately 1000 keypads per mesh
- Each keypad is configured with a specific meter serial number

3.1.4 Meter Communication Devices

- Interface modules attached to electricity meters
- Translate between meter-specific protocols (DLMS, DL/T 645, etc.) and EMOG protocol
- Pre-developed modules available for various meter types
- Specialized modules for specific applications (see Section 3.2)

3.2 Meter Types

3.2.1 Prepaid Meters

- Require STS tokens to activate and maintain power supply
- Tokens typically delivered from HES directly to meter via mesh
- Alternative token delivery via keypad for offline operation
- Display remaining credit in kWh on associated keypad
- Enable gateway deployment without internet connectivity

3.2.2 Smart Meters

- Receive remote connect/disconnect commands from HES
- Display remaining credit in currency on associated keypad
- Support advanced tariff structures and demand management
- Provide detailed consumption data and event logging

3.3 Specialized Communication Modules

3.3.1 Standard Meter Modules

Communication modules have been developed for common meter types, supporting industry-standard protocols including DLMS and DL/T 645.

3.3.2 Generator Monitor Modules

Specialized modules for meters monitoring generator installations:

- Monitor generator status and operation
- Transmit special commands across the mesh network when generator starts
- Control meter register switching to differentiate energy consumption sources

- Enable separation of grid-supplied energy from generator-supplied energy

3.3.3 Solar Rooftop Modules

Specialized modules for installations with rooftop solar systems:

- Monitor both energy import and export
- Implement export limitation controls
- Ensure exported energy does not exceed imported energy
- Support net metering and self-consumption monitoring

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4. Network Topology

4.1 Mesh Network Architecture

The infrastructure employs a true mesh topology where nodes can communicate with multiple neighboring nodes, creating redundant communication paths.

Key Characteristics:

- **Self-organizing**: Nodes automatically discover neighbors and establish optimal routing paths
- **Multi-hop communication**: Data can traverse multiple nodes to reach its destination
- **Dynamic routing**: Network automatically adapts to changing conditions and node availability
- **Load balancing**: Traffic is distributed across available paths
- **Hierarchical levels**: Nodes are organized in levels based on proximity to gateways

4.2 Network Level Hierarchy

The EMOG protocol implements a hierarchical network structure:

- **Level 0**: Gateways - interface to HES
- **Level 1**: Nodes (meter-nodes and keypads) that can communicate directly with a gateway
- **Level 2**: Nodes that communicate with Level 1 nodes (cannot reach gateway directly)
- **Level 3+**: Additional levels as needed for network coverage

Each node determines its level based on its position in the mesh and communicates this level in all messages. Nodes maintain knowledge of their parent node (the upstream node in the path to the gateway). This hierarchy enables efficient routing and helps prevent routing loops.

4.3 Network Identifier (PAN)

The Personal Area Network (PAN) identifier is used to logically separate networks:

- **Default PAN**: 20
- **Purpose**: Forces networks to remain separate even when in physical proximity
- **Use Case**: Overlapping networks in dense deployment areas can be configured with different PAN identifiers
- **Configuration**: Nodes can be configured to operate on alternative PAN identifiers to prevent cross-network communication

4.4 Gateway Association and Mesh Formation

Normal Operation (Multiple Active Gateways):

When multiple gateways are operational, the mesh network automatically partitions into separate logical meshes:

- Each node automatically associates with the most suitable gateway based on signal quality and hop count
- Nodes maintain awareness of alternative gateways for failover purposes
- Each logical mesh operates independently while sharing the same physical infrastructure
- All nodes within a mesh share the same PAN identifier

Gateway Failure and Network Reconfiguration:

When a gateway becomes unavailable:

1. Nodes previously associated with the failed gateway detect the loss of connectivity
2. Automatic reassociation process begins
3. Orphaned nodes connect to remaining active gateways
4. Two or more logical meshes merge into a single mesh under the remaining gateway(s)
5. Network routing tables are automatically updated
6. Node levels are recalculated based on new gateway associations
7. Parent node relationships are reestablished
8. Communication is restored with minimal disruption

Gateway Recovery:

When a failed gateway returns to service:

- Nodes may gradually reassociate to optimize network distribution

- The mesh may split again into multiple logical networks
- Reassociation occurs without service interruption
- Node levels adjust based on optimal gateway selection

4.5 Typical Network Scale

A representative mesh deployment includes:

- **Meter-nodes**: ~50 devices
- **Keypads**: ~1000 devices
- **Meters per meter-node**: Up to 100
- **Total meters supported**: Up to 5000 per mesh
- **Gateways**: 1 or more (for redundancy)
- **Network levels**: Typically 1-4 levels deep

4.6 Network Topology Diagrams

Refer to Section 12 for detailed visual representations of:

- Meter-node mesh network topology showing hierarchical levels and mesh connections
- Keypad integration showing communication paths through gateways

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5. EMOG Protocol Overview

5.1 Protocol Name and Key Features

The EMOG Protocol (Encrypted, Mesh, Own-Generation) derives its name from three fundamental characteristics:

1. **Encrypted**: Message payloads are encrypted to ensure security and privacy
2. **Mesh**: Packets are distributed across a self-healing radio mesh network
3. **Own-Generation**: Support for own-generation metering methodology in sites with backup power

5.2 Message Direction

The EMOG protocol defines two message directions:

- **UP Messages**: Sent from nodes toward the gateway (uplink)
  - Start byte: E2h
  - MAC field contains the originating node address

    - Used for meter data, node definitions, and status reports
- **DOWN Messages**: Sent from gateway toward destination nodes (downlink)
    - Start byte: E1h
    - MAC field contains the destination node address
    - Used for commands, configuration, and time synchronization

5.3 Message Types

The EMOG protocol defines four message types:

5.3.1 Message Type 1: Meter Registers Info

- **Direction**: UP
- **Purpose**: Transmit meter reading data from meters to HES
- **Content**: Device ID, register count, and register values in pipe-delimited format
- **Frequency**: Periodic or on-demand
- **Example Body**: 1.8.0=26581|1.7.0=16.8|C.1.0=208.7

5.3.2 Message Type 2: Node Definition

- **Direction**: UP
- **Purpose**: Report node configuration and network topology information
- **Content**: Node MAC, level, firmware version, parent MAC, node name, RSSI
- **Frequency**: Periodic and on network changes
- **Fixed Length**: 50 bytes (excluding start byte and CRC)

5.3.3 Message Type 3: Command Message

- **Direction**: DOWN
- **Purpose**: Send commands from HES to specific meters or request data
- **Content**: Target device ID, command name (20 chars), and variable payload
- **Use Cases**:
    - STS token delivery (command: "TOKEN")
    - Register read requests (command: register name, payload length: 0)
    - Register write operations (command: register name, payload: new value)
    - Time/date configuration
    - TOU tariff programming (payload up to 140 characters)

5.3.4 Message Type 4: Time Sync Message

- **Direction**: DOWN
- **Purpose**: Synchronize time across all meters in the network
- **Content**: Timestamp in yyyyMMddHHmmss format
- **Frequency**: Regular intervals to maintain time accuracy
- **Fixed Length**: 35 bytes (excluding start byte and CRC)

Detailed message structure specifications are provided in Appendix A.

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6. Keypad Functionality

6.1 Overview

Keypads serve as the primary user interface for both prepaid and smart meters, allowing consumers to interact with their electricity meters and view account information. Keypads are integrated into the mesh network as nodes with their own network levels.

6.2 Keypad Configuration

Each keypad is configured with:

- Specific meter serial number that it is associated with
- Network credentials (PAN identifier)
- Display preferences and language settings

6.3 Display Functionality

Keypads display information from both the meter and the HES:

For Prepaid Meters:

- Remaining credit displayed in kWh
- Low credit warnings
- Token entry confirmation
- Meter status information

For Smart Meters:

- Remaining credit displayed in currency (e.g., Rand, Dollar)
- Consumption information
- Tariff information
- Meter status information

6.4 STS Token Delivery

The system supports two methods for STS token delivery to prepaid meters:

6.4.1 Primary Method: Direct Delivery via Mesh

- HES generates token and sends to gateway
- Gateway routes token through mesh to meter-node
- Meter-node delivers token to meter
- Requires active gateway-to-HES connection

6.4.2 Alternative Method: Keypad Entry

- Token sent to customer via SMS or other means
- Customer enters token on their keypad
- Keypad sends token through mesh to gateway
- Gateway routes token to meter via meter-node
- Enables offline operation when HES connection unavailable

6.4.3 Offline Gateway Operation

- If all meters in a deployment are prepaid meters, gateways can operate without internet connectivity
- Tokens delivered to customers via SMS
- Customers enter tokens on keypads
- Tokens are delivered to meters entirely through local mesh network
- Enables deployment in areas with limited or no internet connectivity

6.5 Special Command Access

Keypads support special command codes that allow users to access meter information:

- Meter reading queries
- Meter status checks
- Current time verification
- Instantaneous power consumption
- Other meter-specific information

Note: Detailed keypad operation, command codes, and user instructions are provided in the separate Keypad User Manual.

6.6 Communication Architecture

Critical Design Principle: Keypads do not communicate directly with meters. All keypad-to-meter communication follows this path:

1. User enters command or token on keypad
2. Keypad sends message to gateway (as an UP message if keypad initiates, or receives DOWN message from gateway)
3. Gateway processes request and routes to appropriate meter-node
4. Meter-node communicates with meter using meter protocol
5. Response follows reverse path: Meter → Meter-node → Gateway → Keypad

This architecture ensures:

- Centralized control and monitoring through gateway
- Consistent security and encryption
- Simplified network management
- Audit trail of all user interactions

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7. Own-Generation Functionality

7.1 Purpose and Application

The own-generation feature addresses a specific metering requirement in apartment blocks and similar installations where backup generators provide power during grid outages. This capability ensures accurate energy accounting by separating grid-supplied energy from generator-supplied energy.

7.2 Common Scenarios

- **Load Shedding**: Scheduled power interruptions requiring backup generation
- **Power Failures**: Unplanned outages where generators maintain building power
- **Peak Shaving**: Voluntary use of generators during high-cost periods

7.3 Own-Generation Operation Sequence

Generator Start Sequence:

1. **Detection**: A generator monitor (specialized communication module on the generator meter) detects that the generator has started
2. **Local Mesh Notification**: The generator monitor sends an own-generation command to the gateway of its specific mesh
3. **Command Distribution**: The gateway broadcasts the own-generation command to all meter-nodes in the mesh

4. **Register Switching**: Each meter-node forwards the command to all associated meters, instructing them to switch to alternative energy registers designated for generator-supplied energy
5. **Continuous Confirmation**: The generator monitor sends the own-generation command every minute while the generator continues to run

Multi-Gateway Coordination:

In apartment blocks with multiple gateways:

- The generator monitor communicates with the gateway of its local mesh
- Meters associated with other gateways in the same building receive the own-generation command via the HES
- The HES ensures all meters in the installation switch to generator registers regardless of which mesh they belong to

Failsafe Operation:

- **Timeout Mechanism**: If a meter does not receive the own-generation command within 2 minutes, it automatically reverts to normal (grid) registers
- **Purpose**: Prevents meters from remaining in generator mode if communication is lost
- **Result**: Ensures accurate metering even in degraded network conditions

Generator Stop Sequence:

1. **Detection**: The generator monitor detects that the generator has stopped
2. **Reversion Command**: The generator monitor immediately sends a command to switch all meters back to normal (grid) registers
3. **Distribution**: The command is distributed through the mesh to all meters
4. **Confirmation**: Meters acknowledge the switch back to grid registers

7.4 Register Configuration

Each meter maintains separate registers for different energy sources:

- **Normal Registers**: Record grid-supplied energy consumption
- **Alternative Registers**: Record generator-supplied energy consumption
- **Switching Logic**: Controlled by EMOG protocol commands
- **Independent Tracking**: Allows separate billing or analysis of grid vs. generator consumption

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8. Communication Flow

8.1 Downlink Communication (HES to Meter)

1. HES sends command/request to gateway (outside scope)
2. Gateway transmits DOWN message (E1h) into mesh network with destination MAC
3. Message routes through mesh-nodes based on network levels to destination meter-node
4. Meter-node translates EMOG protocol to meter-specific protocol (DLMS, DL/T 645, etc.)
5. Communication device on meter exchanges data with meter
6. Response follows reverse path back to HES as UP message (E2h)

8.2 Uplink Communication (Meter to HES)

1. Meter communication device initiates communication (periodic reading, alarm, etc.)
2. Device communicates with meter using meter-specific protocol
3. Data is encapsulated in EMOG UP message (E2h) and sent to associated meter-node
4. Meter-node routes data through mesh network toward gateway
5. Message traverses network levels (Level 3 → Level 2 → Level 1 → Level 0)
6. Gateway forwards to HES (outside scope)

8.3 Keypad-to-Meter Communication

1. User interacts with keypad (enters token, requests meter reading, etc.)
2. Keypad sends request message through mesh network toward gateway (UP message)
3. Message routes through parent nodes to gateway based on keypad's level
4. Gateway processes request and creates DOWN message to target meter
5. DOWN message routes to meter-node associated with target meter
6. Meter-node forwards to meter communication device
7. Communication device executes command on meter using meter protocol (DLMS, DL/T 645, etc.)
8. Response follows reverse path as UP message: Meter → Meter-node → Gateway → (routing through levels) → Keypad
9. Keypad displays result to user

8.4 Own-Generation Command Distribution

1. Generator monitor detects generation event

2. Generator monitor sends own-generation command to local mesh gateway (UP message)
3. Gateway broadcasts command to all meter-nodes (DOWN messages)
4. Each meter-node sends register-switching command to all associated meters
5. Command is repeated every minute while generator runs
6. For multi-gateway installations, HES distributes command to other gateways
7. Meters automatically revert to normal registers if command not received within 2 minutes

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9. Protocol Architecture

9.1 Protocol Layers

The communication infrastructure implements a layered protocol architecture:

- **Application Layer**: Meter-specific protocols (DLMS, DL/T 645, etc.)
- **EMOG Protocol Layer**: Mesh networking protocol with encryption
- **Physical Layer**: Radio frequency communication

9.2 Common Message Structure

All EMOG protocol messages share a common header structure:

- **Start Byte**: Identifies message direction (E1h = DOWN, E2h = UP)
- **Message Length**: Total length excluding start byte and CRC
- **MAC Address**: 6-byte address (source for UP, destination for DOWN)
- **Sender Level**: Network level of the sending node
- **PAN**: Network identifier
- **Message Type**: Identifies the message type (1-4)
- **Message Body**: Type-specific content
- **CRC**: 2-byte cyclic redundancy check for error detection

9.3 Meter Protocol Support

The communication devices support multiple meter protocols:

- **DLMS/COSEM**: International standard for meter communication
- **DL/T 645**: Chinese standard for electricity meter communication
- **Proprietary Protocols**: Support for specific meter manufacturer protocols

The EMOG protocol encapsulates these meter-specific protocols, allowing transparent communication between HES and meters regardless of the underlying meter protocol.

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10. System Features

10.1 Reliability and Resilience

- **Multi-path routing**: Multiple routes available for critical data
- **Automatic failover**: Gateway failure does not disrupt service
- **Self-healing network**: Automatic recovery from node failures
- **Redundant gateways**: Multiple gateways provide backup capability
- **Own-generation failsafe**: Automatic reversion if communication lost
- **Offline operation**: Prepaid token delivery without HES connectivity

10.2 Scalability

- Large node capacity (1000+ devices per mesh)
- High meter density (up to 5000 meters per mesh)
- Expandable architecture for growing deployments
- Network level hierarchy supports deep networks

10.3 Security

- Encrypted message payloads
- MAC-based addressing for targeted communication
- CRC error detection on all messages
- Network isolation via PAN identifiers

10.4 Advanced Functionality

- **Own-Generation Metering**: Separate registers for generator-supplied energy
- **Time Synchronization**: Network-wide time accuracy for TOU metering
- **TOU Programming**: Complex tariff structures with up to 140-character configurations
- **Export Limitation**: Control of solar export to match import levels
- **Remote Configuration**: Over-the-air updates and configuration
- **Event Notification**: Real-time alarm and event reporting
- **Network Diagnostics**: RSSI and topology information for monitoring
- **Dual Token Delivery**: Both online and offline prepaid token delivery

11. Deployment Considerations

11.1 Geographic Coverage

The infrastructure is optimized for:

- Clustered meter installations (sub-metering scenarios)
- Distribution transformer supply areas
- Apartment blocks with multiple floors and units
- Urban and suburban deployment densities
- Mixed indoor/outdoor installations
- Remote areas with limited internet connectivity

11.2 Installation Requirements

- Strategic placement of gateways for coverage and redundancy
- Meter-node positioning to ensure connectivity to all meters
- Signal propagation considerations for RF communication
- Power supply requirements for network components
- PAN configuration for overlapping networks
- Keypad placement for user accessibility

11.3 Own-Generation Installations

- Generator monitor module installation on generator meter
- Configuration of alternative registers on all meters
- HES integration for multi-gateway coordination
- Testing of failsafe mechanisms

11.4 Prepaid Metering Deployments

- Gateway configuration for offline operation (if required)
- SMS gateway or alternative token delivery system
- Keypad installation and user training
- Token vending system integration

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12. Network Topology Diagrams

12.1 Diagram 1: Meter-Node Mesh Network Topology

This diagram illustrates the hierarchical mesh network structure with a gateway at Level 0, meter-nodes at Levels 1 and 2, and individual meters communicating with their associated meter-nodes. Mesh connections between nodes provide redundant communication paths.

Key Elements:

- Gateway (Level 0) serves as the central coordination point
- Meter-nodes at Level 1 communicate directly with the gateway
- Meter-nodes at Level 2 route through Level 1 nodes
- Each meter-node connects to multiple meters (shown with 2-3 meters per node for clarity)
- Mesh links between nodes (shown as dashed lines) provide alternative paths
- Primary links (solid green lines) show parent-child relationships

Network Characteristics Shown:

- Hierarchical level structure (Levels 0, 1, 2)
- Multi-path redundancy through mesh connections
- Direct meter-to-meter-node communication
- Scalable architecture supporting additional levels

12.2 Diagram 2: Keypad Integration in EMOG Network

This diagram shows how keypads integrate into the network as nodes with their own levels. Keypads communicate with the gateway, which then routes messages to meters through meter-nodes. Keypads do not communicate directly with meters.

Key Elements:

- Keypads shown at different network levels (Level 1 and Level 2)
- Each keypad is associated with a specific meter (shown by serial number)
- Communication flow annotations demonstrate the complete path
- Example flows show both Level 1 and Level 2 keypad communications

Communication Path Illustrated:

1. User enters command on keypad (e.g., *800# to read meter or STS token)
2. Keypad sends request to gateway through mesh network
3. Gateway routes request to appropriate meter-node
4. Meter-node communicates with meter using meter protocol (DLMS, DL/T 645)

5. Response follows reverse path: Meter → Meter-node → Gateway → Keypad

Important Design Principle: The diagram clearly shows that keypads function as mesh network nodes but do not have direct communication with meters. All keypad-to-meter interaction is mediated through the gateway, ensuring centralized control, security, and monitoring.

Note: Full visual diagrams are available in the separate topology diagrams document.

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13. Future Enhancements

Areas for potential expansion and enhancement:

- Additional meter protocol support
- Enhanced security features (key rotation, certificate management)
- Advanced analytics and diagnostics
- Integration with distribution automation systems
- Support for additional smart grid applications
- Extended own-generation scenarios (solar, wind, storage)
- Mobile application for keypad functionality
- Enhanced offline gateway capabilities

Appendices

Appendix A: EMOG Protocol Message Specifications

Detailed specifications for all four EMOG protocol message types are provided in the following sections.

A.1 Message Type 1: Meter Registers Info

Direction: UP (E2h)
Purpose: Transmit meter reading data from communication device to HES
Length: Variable

Position	Field Name	Length (bytes)	Description
0	Start Byte	1	E1h for Down messages, E2h for Up messages

Position	Field Name	Length (bytes)	Description
1	Message Length	1	Length of entire message excluding the start byte and final CRC check
2	MAC	6	Message originator for up messages, message destination for down messages
8	Sender Level	1	Level of sending Node
9	PAN	1	Network Identifier
10	Message Type	1	1 = Meter Registers
11	Device ID	14	Serial number of the meter
25	CRC	2	2-Byte CRC

Time String Format:

- Year: 4 digits (yyyy)
- Month: 2 digits (MM) - 01 to 12
- Day: 2 digits (dd) - 01 to 31
- Hour: 2 digits (HH) - 00 to 23
- Minute: 2 digits (mm) - 00 to 59
- Second: 2 digits (ss) - 00 to 59

Example:

Time String: "20260117143530"

Represents: January 17, 2026, 14:35:30

Notes:

- Time sync messages can be broadcast to all nodes or sent to specific nodes
- Critical for Time-of-Use (TOU) metering accuracy
- Essential for accurate event timestamping
- Recommended synchronization frequency: Daily or when time drift exceeds threshold
- Time string follows ISO 8601 basic format without separators

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Appendix B: Common Register Names (OBIS Codes)

The following table lists commonly used register names based on OBIS (Object Identification System) codes:

Register	Description	Unit
1.8.0	Total Active Energy Import	kWh
2.8.0	Total Active Energy Export	kWh
1.7.0	Instantaneous Active Power Import	kW
2.7.0	Instantaneous Active Power Export	kW
3.8.0	Total Reactive Energy Import	kvarh
4.8.0	Total Reactive Energy Export	kvarh
1.8.0*1	Total Active Energy Import (Alternative/Generator Register)	kWh
C.1.0	Voltage Phase L1	V
C.2.0	Voltage Phase L2	V
C.3.0	Voltage Phase L3	V
C.7.0	Current Phase L1	A
C.8.0	Current Phase L2	A
C.9.0	Current Phase L3	A
C.5.0	Power Factor	-
0.9.1	Time/Date	-
0.9.2	Date	-

Notes:

- Registers with asterisk notation (e.g., 1.8.0*1) indicate tariff registers or alternative registers
- DL/T 645 protocol uses different register naming conventions
- Consult meter manufacturer documentation for complete register lists
- Register availability varies by meter model and configuration

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Appendix C: CRC Calculation Method

(To be provided - will detail CRC polynomial and calculation procedure)

Appendix D: Encryption Specifications

Encryption Method: AES (Advanced Encryption Standard) with 128-bit key

Encrypted Fields:

- Message Body field in Message Type 1 (Meter Registers Info) is encrypted

Key Characteristics:

- User-configurable encryption key
- Each deployment can use a unique encryption key for security
- Key must be 128 bits (16 bytes)
- Key configuration performed during system commissioning

Message Body Padding:

- The Message Body is always padded to a length that is a multiple of 16 bytes
- Padding character: char(0) (null character)
- Example: If unencrypted message body is 45 bytes, it is padded to 48 bytes (next multiple of 16)

Encryption Process:

1. Prepare message body in pipe-delimited format
2. Calculate required padding (round up to next multiple of 16)
3. Append char(0) padding bytes
4. Encrypt padded message body using AES-128
5. Insert encrypted message body into message structure

Decryption Process:

1. Extract encrypted message body from message
2. Decrypt using AES-128 with configured key
3. Remove padding (char(0) bytes from end)
4. Parse pipe-delimited register data

Security Notes:

- Encryption key must be kept secure and confidential
- Different installations should use different encryption keys

- Key distribution should follow secure procedures during commissioning
- Regular key rotation is recommended for high-security installations

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Appendix E: Network Configuration and Commissioning Guide

(To be provided - will include step-by-step procedures for network setup)

Appendix F: Gateway Hardware Specifications

(To be provided - will include technical specifications for gateway devices)

Appendix G: Troubleshooting Guide

(To be provided - will include common issues and resolution procedures)

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Status: Draft - Pending Review Register Count | 1 | Number of registers included in message body | | 26 | Message Body | N | Register data in pipe-delimited format | | N + 26 | CRC | 2 | 2-Byte CRC |

Message Body Format:

The message body contains register data in pipe-delimited format:

Register-Name=Register-Value|Register-Name=Register-Value|...

Example:

1.8.0=26581|1.7.0=16.8|C.1.0=208.7

This example shows three registers:

- Register 1.8.0 (Total Active Energy Import) = 26581 kWh
- Register 1.7.0 (Instantaneous Active Power) = 16.8 kW
- Register C.1.0 (Voltage Phase L1) = 208.7 V

Characteristics:

- Pipe character (|) separates individual register entries
- Equals sign (=) separates register name from register value
- Register count field must match the number of pipe-delimited entries
- Register names follow OBIS code conventions or meter-specific naming

- Values are transmitted as decimal strings
- Variable length accommodates different numbers of registers per message

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A.2 Message Type 2: Node Definition

Direction: UP (E2h)
Purpose: Report node configuration and network topology information
Length: Fixed at 50 bytes (excluding start byte and CRC)

Position	Field Name	Length (bytes)	Description
0	Start Byte	1	E2h (Up message)
1	Message Length	1	Length of entire message excluding the final CRC check = 50
2	MAC	6	Node MAC address
8	Sender Level	1	Level of sending Node
9	PAN	1	Network Identifier
10	Message Type	1	2 for Node definition
11	Level	1	Node Level (redundant with Sender Level for validation)
12	Firmware Version	14	Version string of node firmware
26	Parent MAC	6	MAC address of parent node in routing hierarchy
32	Node Name	20	Human-readable node identifier
52	RSSI	1	Absolute value of RSSI (Received Signal Strength Indicator)
53	CRC	2	2-Byte CRC

Notes:

- Node definition messages are sent periodically to maintain network topology awareness
- Parent MAC indicates the node's immediate upstream neighbor in the routing path to gateway
- For Level 1 nodes, Parent MAC is the gateway's MAC address

- RSSI value helps assess link quality and optimize routing
- Firmware version enables remote monitoring of node software versions
- Node name can be configured for easy identification in network management systems

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A.3 Message Type 3: Command Message

Direction: DOWN (E1h)
Purpose: Send commands from HES to specific meters or request data
Length: Variable

Position	Field Name	Length (bytes)	Description
0	Start Byte	1	E1h for Down messages
1	Message Length	1	Length of entire message excluding the start byte and final CRC check
2	MAC	6	Destination MAC address
8	Sender Level	1	Level of sending Node
9	PAN	1	Network Identifier
10	Message Type	1	3 for command
11	Device ID	14	Serial number of the target meter
25	Command	20	Command identifier or register name
45	Payload Length	1	Length of variable payload data
46	Payload	N	Command-specific data
N + 46	CRC	2	2-Byte CRC

Command Types:

1. STS Token Delivery

- Command field: "TOKEN"
- Payload: STS token string (20 digits)
- Payload Length: 20
- Used for prepaid meter token delivery

2. Register Read Request

- Command field: Register name (e.g., "1.8.0", "2.8.0", "1.8.0*1")
- Payload Length: 0
- Payload: Empty
- Meter responds with Message Type 1 containing requested register value

3. Register Write Operation

- Command field: Register name
- Payload: New value to write to register
- Payload Length: Length of value string
- Used for configuration, tariff updates, and parameter changes

4. Time/Date Configuration

- Command field: Date/time register name
- Payload: Date/time value
- Payload Length: Varies based on register format
- Used to synchronize individual meter clocks

5. Time-of-Use (TOU) Programming

- Command field: TOU register name
- Payload: TOU configuration data (up to 140 characters)
- Payload Length: Up to 140
- Used to configure complex tariff schedules
- Format defined by meter manufacturer

Examples:

Token delivery:

Command: "TOKEN"

Payload Length: 20

Payload: "12345678901234567890"

Read total energy:

Command: "1.8.0"

Payload Length: 0

Payload: (empty)

Configure TOU tariff:

Command: "TOU_SCHEDULE_1"

Payload Length: 85

Payload: "WEEKDAY:00:00-06:00,TARIFF1;06:00-18:00,TARIFF2;18:00-24:00,TARIFF3"

A.4 Message Type 4: Time Sync Message

Direction: DOWN (E1h)
Purpose: Synchronize time across all meters in the network
Length: Fixed at 35 bytes (excluding start byte and CRC)

Position	Field Name	Length (bytes)	Description
0	Start Byte	1	E1h for Down messages
1	Message Length	1	Length of entire message excluding the start byte and final CRC check
2	MAC	6	Destination MAC address
8	Sender Level	1	Level of sending Node
9	PAN	1	Network Identifier
10	Message Type	1	4 = Time sync message
11	Time String	14	Time in format: yyyyMMddHHmmss
25	CRC	2	2-Byte CRC