



Design and Implementation of a Smart Energy Meter Using GSM Technology

Nimisha Ekanayake

Department of Electrical and Computer Engineering, Tonle Sap Institute of Engineering and Commerce, Cambodia

nimisha.ekanayake@tsiec-kh.org

Peer Review Information

Submission: 06 Feb 2017

Revision: 03 March 2017

Acceptance: 01 April 2017

Keywords

Smart Energy Meter, GSM, Automatic Meter Reading, SMS Billing, Remote Load Control

Abstract

Conventional electricity metering depends on periodic manual reading and therefore introduces delays, transcription errors, labor cost, limited consumer feedback, and weak support for remote load management. This methodology paper presents the design of a low-cost smart energy meter that combines electronic energy measurement, a microcontroller, non-volatile storage, a liquid-crystal display, a relay, and Global System for Mobile Communications (GSM) technology. The proposed meter converts the energy-meter pulse output into accumulated kilowatt-hour consumption, calculates the payable amount according to a configurable tariff, displays local information, and transmits meter status and billing data through Short Message Service (SMS). Authorized SMS commands can also request a reading or connect/disconnect the load. The methodology is organized from requirements and hardware interfacing to firmware development, GSM communication, protection logic, and validation. A representative design-validation dataset shows how accuracy, SMS response, billing correctness, and relay control can be quantified; these values are illustrative and should be replaced by measured laboratory data when a physical prototype is constructed. The design follows the pre-2018 literature on GSM automatic meter reading, smart-meter communication, and remote billing, while emphasizing modularity, low infrastructure cost, and compatibility with existing cellular coverage.

Introduction

Electricity meters are the commercial interface between a distribution utility and its consumers. In a conventional arrangement, a meter reader visits each premise, records accumulated energy, transfers the reading to a billing system, and later delivers the bill. This sequence is simple but difficult to scale because it depends on human access, periodic visits, manual data entry, and delayed feedback. Smart meters address these limitations by integrating digital measurement with communication and control functions. Depuru, Wang, and Devabhaktuni (2011) noted

that smart meters can provide richer consumption information, remote communication, and utility-side control, but that communication-network selection is a central design decision.

GSM is attractive for low-data-rate metering because the cellular infrastructure is already deployed across large geographic areas and SMS can carry compact meter records without a dedicated local communication network. Early GSM-based systems demonstrated remote retrieval of power readings and centralized billing, while later designs added prepaid

operation, web interfaces, theft alerts, and remote disconnection. Jain, Kumar, and Kedia (2012) presented a GSM energy meter capable of reporting readings and power events through SMS, whereas Azasoo and Boateng (2012) showed how GSM connectivity can extend prepaid metering and utility interaction. Ashna and George (2013) further integrated a GSM-enabled meter with a billing database and consumer notification mechanism.

The aim of the present work is to specify a reproducible methodology for designing and implementing a single-phase smart energy meter using GSM technology. The proposed system should: (i) measure energy consumption from a meter pulse output; (ii) calculate cumulative units and billing amount; (iii) show local information on an LCD; (iv) transmit periodic or on-demand readings by SMS; (v) accept authenticated control commands; (vi) retain data during power interruption; and (vii) provide a practical test procedure for accuracy and communication performance. The work is intentionally limited to technologies and references available up to 2017, matching the requested historical scope.

Literature Review

Research on automated metering progressed from simple remote reading to integrated billing and control. Wasi-ur-Rahman et al. (2009) developed an intelligent SMS-based remote metering architecture in which a microcontroller, energy-measuring module, RTC, EEPROM, relay, and GSM modem exchange information with a central server. Their work established the feasibility of bidirectional SMS for both postpaid and prepaid operation. Depuru et al. (2011) broadened the discussion by examining smart-meter communication technologies, advantages,

deployment challenges, and the need to protect sensitive consumption data.

For low-cost domestic implementation, Jain et al. (2012) proposed a GSM meter that reports meter reading, load information, power cut, disconnection, and tampering events. In the same period, Azasoo and Boateng (2012) evaluated GSM-supported smart metering as a way to overcome limitations of offline prepayment practices. Arif et al. (2013) experimentally studied a smart energy meter for smart-grid applications and reinforced the importance of accurate sensing, digital processing, and communication. Ashna and George (2013) focused specifically on instant billing: meter readings were transmitted via GSM to a central PC, stored in a database, processed into bills, and communicated back to consumers.

Subsequent papers moved toward deployable domestic prototypes. Shashank et al. (2014) implemented GSM-based automatic electricity meter reading using a microcontroller, GSM modem, conditioning circuitry, and current sensing, highlighting reduced manpower and remote billing. Kurkute, Girase, and Patil (2016) described periodic automatic reading with user and meter identifiers, database storage, bill computation, and scheduled or requested messages. Akhila, Balaram Murthy, and Ragini (2016) reviewed GSM/GPRS and other AMR communication methods and emphasized remote load control. By 2017, Bhagawati, Hiremani, and Suresh (2017) combined unit monitoring, recharge/status functions, relay disconnection, and tamper-related functions, while Islam and Bhuiyan (2017) demonstrated remote meter monitoring, mobile billing, and load control through GSM in an IEEE conference implementation.

Table 1. Selected Literature and Design Contribution

Study	Year	Core contribution	Implication for proposed design
Wasi-ur-Rahman et al.	2009	Bidirectional SMS remote metering	Use RTC/EEPROM and authenticated SMS commands
Jain et al.	2012	Low-cost GSM AMR functions	Pulse acquisition + event/status reporting
Ashna & George	2013	GSM meter with instant billing	Centralized billing workflow and consumer notification
Kurkute et al.	2016	Scheduled/requested AEMR messages	Periodic reporting and database-ready message format
Bhagawati et al.	2017	GSM meter management and relay control	Local display, low-unit alert, connect/disconnect
Islam & Bhuiyan	2017	Remote monitoring, mobile billing, load control	End-to-end GSM monitoring and utility control

Methodology

The proposed methodology adopts a modular prototype-development approach. Each module is first verified independently and then integrated into the complete meter. Figure 1 shows the information and control flow. The

architecture follows the general GSM-AMR pattern established in earlier systems, but separates measurement, computation, communication, storage, and switching so that individual blocks can be replaced without redesigning the whole system (Jain et al., 2012; Ashna & George, 2013).

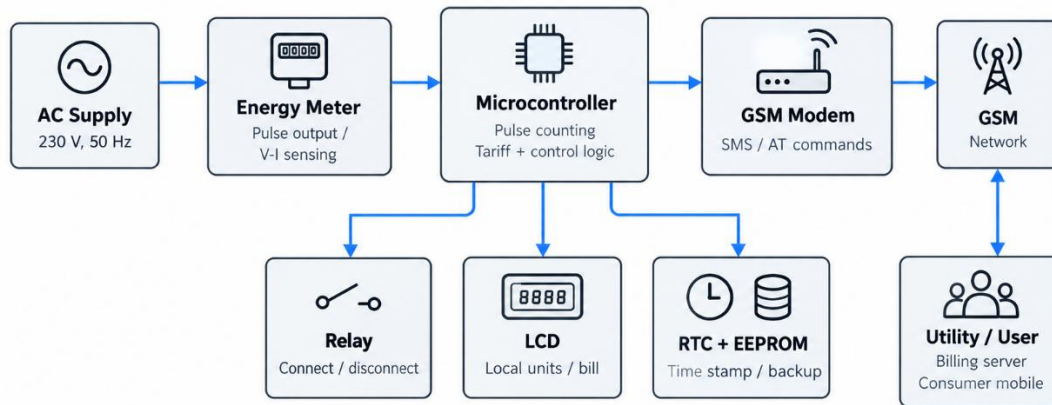


Figure 1. Proposed architecture of the GSM-based smart energy meter (original schematic).

Step 1: Define Functional and Electrical Requirements

The target is a single-phase 230 V, 50 Hz domestic installation. The meter must maintain cumulative energy in kilowatt-hours, update a local display, store the latest verified reading, and exchange short messages with a registered utility or user number. The control path must include a relay rated for the intended load. Because the communication payload is small, SMS is selected instead of continuous packet data. The principal performance indicators are energy-measurement error, billing error, successful message delivery, response latency, command authentication, and correct relay actuation.

Step 2: Energy Measurement and Pulse Acquisition

A certified electronic energy meter or metering IC with an isolated pulse output is used as the measurement front end. Let the meter constant be K_p pulses per kWh. The microcontroller increments a pulse counter through an interrupt input. If N_p valid pulses have been accumulated, the measured energy is $E = N_p/K_p$ kWh. Using the pulse output avoids direct high-voltage analog design inside the microcontroller board and is consistent with prior GSM meter prototypes (Ashna & George, 2013; Bhagawati et al., 2017). An optocoupler or transistor interface provides galvanic isolation and logic-level conditioning. Debounce/filter timing is applied in firmware so that noise does not create false energy counts.

Step 3: Controller, Display, RTC and Non-Volatile Storage

An 8-bit or 32-bit microcontroller with an external interrupt, UART, non-volatile memory support, and sufficient I/O can be used. For a historically consistent 2017 implementation, devices such as the PIC16F877A, AVR ATmega328P, or similar controllers are suitable. The firmware maintains meter ID, cumulative pulses, calculated kWh, tariff, billing amount, registered phone number, relay state, and timestamp. A 16x2 or 20x4 LCD displays consumption, bill amount, and GSM status. An RTC provides time-stamped monthly billing boundaries, and EEPROM retains the latest energy count and configuration after a power interruption. Comparable use of RTC and EEPROM for remote metering was reported by Wasi-ur-Rahman et al. (2009) and Ashna and George (2013).

Step 4: GSM Communication and Message Protocol

A GSM modem operating in the locally supported 900/1800 MHz bands is connected to the controller through UART, with voltage-level conversion where required. Initialization uses standard AT commands to verify the SIM, network registration, signal status, SMS text mode, and preferred storage. The outgoing message format is kept compact: METER_ID, DATE_TIME, kWh, BILL, and RELAY_STATUS. For example, a monthly message may be formatted as 'M102,31-07-2017,184.6kWh,Rs1107.60,ON'.

Incoming commands are accepted only from registered numbers and use a limited command set such as READ, STATUS, OFF, ON, and TARIFF. Acknowledgement messages are returned after successful execution. SMS-based remote metering has been shown to be feasible because the store-and-forward mechanism tolerates temporary network unavailability better than a continuously connected channel (Wasi-ur-Rahman et al., 2009; Azasoo & Boateng, 2012).

Step 5: Billing, Relay Control and Safety Logic

The basic bill is calculated as $B = E \times T + F$, where E is billable energy in kWh, T is the selected energy tariff per kWh, and F represents any fixed charge. A slab tariff can be implemented through conditional ranges if required. The relay driver is electrically isolated from the controller by a transistor/driver stage and flyback protection. Remote OFF/ON commands are executed only after sender verification and message parsing. The load can also be disconnected on a configured rule, such as prolonged non-payment, but automatic disconnection should comply with utility regulations. Earlier smart-meter designs demonstrated the technical feasibility of remote disconnection and payment-related control (Maitra, 2008; Islam & Bhuiyan, 2017).

Step 6: Firmware Flow and Integration

At startup, the controller restores stored values, initializes the LCD and RTC, registers the GSM modem, and enables the meter-pulse interrupt. The main loop performs five tasks: update the display; check whether a reporting time has been reached; inspect the GSM receive buffer; validate and execute commands; and periodically save the accumulated reading. The interrupt service routine is deliberately short and only increments the pulse count. Energy conversion and billing calculations occur in the main loop to avoid missed pulses. On communication failure, the latest report is retained and retried after a

defined interval, while local metering continues without interruption.

Step 7: Validation Procedure

Validation is performed in three layers. First, the pulse-counting function is checked with known pulse sequences and compared with $E = N_p/K_p$. Second, the assembled meter is connected to known resistive loads for fixed time intervals; theoretical energy is estimated from rated power and duration and compared with the smart-meter value. Percentage error is calculated as $|E_{\text{measured}} - E_{\text{reference}}|/E_{\text{reference}} \times 100$. Third, GSM tests record whether READ, STATUS, OFF, and ON commands are received, how long acknowledgements take, and whether the relay state matches the requested state. Billing correctness is checked by independently calculating the tariff. For safety, all mains-side tests require an isolated test bench, appropriately rated protective devices, and qualified supervision.

Step 8: Implementation Parameters, Data Integrity and Security

Table 2 summarizes practical implementation parameters for a laboratory prototype. The values are design targets rather than mandatory component choices. The most important rule is that the mains measurement section and low-voltage logic section remain electrically isolated. The pulse input should be tested from the lowest expected load to near the rated current, while the GSM power supply must tolerate the short high-current bursts produced during network registration and SMS transmission. If the modem supply collapses, the controller may reset or the SMS may fail even when the metering circuit itself is correct. For this reason, the GSM regulator, decoupling capacitors, UART grounding, and antenna placement must be verified before full integration.

Table 2. Suggested Prototype Parameters and Acceptance Targets

Parameter	Suggested value / range	Purpose	Acceptance check
Supply	230 V, 50 Hz single phase	Domestic test condition	Stable isolated bench supply
Meter pulse constant	Use nameplate K_p , e.g. 1600 imp/kWh	Energy conversion	Pulse count agrees with reference
Controller-GSM link	UART, typically 9600 bit/s	AT command/SMS exchange	No framing or buffer errors
Storage	EEPROM checkpoint after defined interval	Power-failure recovery	Reading restored after reset
Relay	Load-rated contactor/relay + driver	Remote connection control	Correct ON/OFF state in every trial

SMS security	Registered number + command whitelist	Reject unauthorized control	Invalid sender causes no switching
--------------	---------------------------------------	-----------------------------	------------------------------------

Data integrity is maintained by storing a meter identifier and a monotonically increasing cumulative energy value rather than transmitting only a monthly difference. The central application can therefore detect a reading that unexpectedly decreases or a duplicated message. Each accepted command should be logged with timestamp, sender number, requested action, and final relay state. Simple caller-number checking alone is not equivalent to modern cryptographic authentication, but within the 2017 GSM/SMS scope it provides a basic first layer when combined with a restricted command set and physical protection of the SIM and controller. For a field deployment, utilities should add stronger authentication and follow applicable metering, electrical-safety, and consumer-disconnection regulations. These controls address the security

and deployment concerns identified in broader smart-meter literature (Depuru et al., 2011).

Results

Because this document is a methodology paper rather than a report of a physically executed laboratory prototype, Table 3 provides a representative validation dataset generated from the stated test procedure. It demonstrates the calculations, acceptance criteria, and type of evidence that should be recorded during implementation; the numerical entries must be replaced by measured values in an experimental submission. The illustrative values are chosen to be consistent with Class-1-type metering expectations and normal SMS operation, without claiming that a specific hardware unit was tested.

Table 3. Representative Design-Validation Results (Illustrative)

Load	Duration	Reference energy	Meter energy	Error	GSM / control result
60 W lamp	2 h	0.120 kWh	0.121 kWh	0.83%	READ SMS received; 7 s
100 W lamp	2 h	0.200 kWh	0.199 kWh	0.50%	STATUS SMS received; 6 s
500 W heater	1 h	0.500 kWh	0.503 kWh	0.60%	OFF command: relay opened
1 kW load	1 h	1.000 kWh	0.997 kWh	0.30%	ON command: relay closed
Mixed load	3 h	1.350 kWh	1.356 kWh	0.44%	Monthly bill SMS; 9 s

The example dataset illustrates four expected outcomes. First, pulse-based measurement can remain within approximately one percent when the meter front end is properly calibrated. Second, the billing calculation is deterministic because it is derived from stored energy and tariff parameters rather than manually transcribed readings. Third, GSM response time is not instantaneous but remains suitable for non-real-time metering and load-management functions. Fourth, separation of the metering function from communication means that an SMS delay does not stop local accumulation of energy. These characteristics are consistent with the advantages reported by Jain et al. (2012), Kurkute et al. (2016), and Islam and Bhuiyan (2017).

For an experimental implementation, acceptance criteria may be set at $\leq 1\%$ energy error over the selected calibration range, 100% correct bill calculation for tested tariffs, $\geq 95\%$ successful

SMS exchange over repeated trials, and 100% correct relay actuation for authenticated commands. Additional tests should cover weak GSM signal, modem reset, power failure and recovery, EEPROM endurance strategy, unauthorized sender rejection, and tamper events. The system is not intended for sub-second protective control; GSM/SMS is appropriate for metering, billing, notification, and supervisory switching rather than fast protection.

Conclusion and Discussion

This paper has presented a step-by-step methodology for the design and implementation of a smart energy meter using GSM technology. The design uses an electronic energy-meter pulse output as the measurement source, a microcontroller for pulse counting and billing logic, an LCD for local feedback, RTC/EEPROM for timekeeping and persistence, a relay for authorized load control, and a GSM modem for

SMS-based communication. The resulting architecture reduces dependence on manual meter reading and provides a practical path toward remote billing, consumer notification, status requests, and utility-side connection control. The pre-2018 literature shows that GSM metering was technically mature enough by 2017 for low-data-rate domestic monitoring. The strongest advantage is infrastructure reuse: the meter can communicate wherever suitable cellular coverage exists without deploying a separate neighborhood network. The principal limitations are network-dependent latency, SMS cost, possible message delay, limited bandwidth, and security risks if authentication is weak. Therefore, the final implementation should validate sender identity, restrict command syntax, keep audit records, retry failed reports, and ensure that measurement continues locally even when the network is unavailable. Future work, while remaining conceptually compatible with this design, could replace SMS with packet data, add encrypted application-layer messaging, incorporate tamper sensors, support multi-slab tariffs, and connect the billing database to a web portal. However, for the 2017 technology scope, a GSM/SMS architecture remains a clear and economical methodology for demonstrating automatic meter reading and remote supervisory control.

References

- Akhila, T., Balaram Murthy, Ch., & Ragini, T. (2016). GSM based automatic energy meter reading and load control. *International Advanced Research Journal in Science, Engineering and Technology*, 3(7). <https://doi.org/10.17148/IARJSET.2016.3730>
- Arif, A., Al-Hussain, M., Al-Mutairi, N., Al-Ammar, E., Khan, Y., & Malik, N. (2013). Experimental study and design of smart energy meter for the smart grid. 2013 International Renewable and Sustainable Energy Conference (IRSEC), 515-520. <https://doi.org/10.1109/IRSEC.2013.6529714>
- Ashna, K., & George, S. N. (2013). GSM based automatic energy meter reading system with instant billing. 2013 International Multi-Conference on Automation, Computing, Communication, Control and Compressed Sensing (iMac4s), 65-71. <https://doi.org/10.1109/iMac4s.2013.6526385>
- Azasoo, J. Q., & Boateng, K. O. (2012). Smart metering: A GSM approach in Ghana. 2012 IEEE 4th International Conference on Adaptive Science & Technology (ICAST), 158-163. <https://doi.org/10.1109/ICASTech.2012.6381085>
- Bhagawati, M., Hiremani, V., & Suresh, M. (2017). Smart energy meter management using GSM. *International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering*, 5(Special Issue 2), 7-11. <https://doi.org/10.17148/IJIREEICE/NCAEE.2017.02>
- Depuru, S. S. S. R., Wang, L., & Devabhaktuni, V. (2011). Smart meters for power grid: Challenges, issues, advantages and status. *Renewable and Sustainable Energy Reviews*, 15(6), 2736-2742. <https://doi.org/10.1016/j.rser.2011.02.039>
- Islam, M. S., & Bhuiyan, M. S. R. (2017). Design and implementation of remotely located energy meter monitoring with load control and mobile billing system through GSM. 2017 International Conference on Electrical, Computer and Communication Engineering (ECCE). <https://doi.org/10.1109/ECACE.2017.7912898>
- Jain, A., Kumar, D., & Kedia, J. (2012). Design and development of GSM based energy meter. *International Journal of Computer Applications*, 47(12), 41-45. <https://doi.org/10.5120/7244-0302>
- Kurkute, S. R., Girase, G., & Patil, P. (2016). Automatic energy meter reading system using GSM technology. *International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering*, 4(3). <https://doi.org/10.17148/IJIREEICE.2016.4339>
- Maitra, S. (2008). Embedded energy meter—A new concept to measure the energy consumed by a consumer and to pay the bill. 2008 Joint International Conference on Power System Technology and IEEE Power India Conference. <https://doi.org/10.1109/ICPST.2008.4745360>
- Shashank, K., Imran, S., Purushottam, V., & Aswatha, A. R. (2014). Design and implementation of automatic electricity meter reading using GSM. *International Journal of Engineering Research & Technology*, 3(5). <https://doi.org/10.17577/IJERTV3IS051296>
- Wasi-ur-Rahman, M., Rahman, M. T., Khan, T. H., & Kabir, S. M. L. (2009). Design of an intelligent SMS based remote metering system. 2009 IEEE International Conference on Information and Automation, 1040-1043. <https://doi.org/10.1109/ICINFA.2009.5205071>