Design of Consumer Participative Device for Smart Grid Initiative

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***Abstract*—This paper will discuss about design of consumer participative device for smart grid initiative. Indonesia condition is taken as the case, because smart grid initiative will depend on object and environment condition. It is found that electricity provider has difficulties to provide Advance Metering Infrastructure (AMI), and that will be the area where consumer most probably be able to contribute for smart grid. As consumer device, it should be designed to give additional benefits for consumer at affordable cost. Functionality requirements of the device for customer benefits are mapped. A smart metering device is designed and proposed, which has capability to collect data and report to electricity provider via IP network, without interfering existing provider's traditional meter. It is based on a low cost microcontroller with GSM/GPRS communication capability and optional autoswitch function to alternative source of energy. The experiment is done by making the device prototype. It shows that customer benefits and cost constraint can be achieved with proper design of the device, to make feasible this consumer participative device concept for smart grid initiative.**

***Keywords*—electricity distribution, smart grid, energy meter, advance metering infrastructure.**

I. Introduction

Indonesian, one of developing country in South East Asia, has average economy growth 5.9% in 2009-2013, which in the coming years is forecasted to increase more than 6%. Its current energy mix is 51.66% oil, 28.57% natural gas, 15.34% coal, 3.11% hydro power, and 1.32% geothermal. In 2025, Indonesia has target to optimize primary energy mix, so that consist of 33% coal, 30% gas, 20% oil, and the rest 17% from biofuel, biomass, geothermal, solar, wind power, and other sources [1].

Despite the increasing of economy growth and optimization target of energy mix, nowadays Indonesia still suffers power shortage. There are problems with the lack of generation capacity and power cuts ranging to several hours in many cities. The condition is likely to get worse over the next few years, waiting for accomplishment of power generator projects in some areas.

Indonesia government via Ministry for Energy and Mineral Resources and Coordinating Ministry for Economic Affairs prepares coordination and preparation of Energy Policy Planning, and synchronizes the implementation, monitoring, analysis, and evaluation of policy implementation in energy and mineral resources. Recently they announced the national program to improve energy efficiency in industrial as well as commercial and residential sectors, which includes the smart grid development.

Smart grid is the modernization of the electricity delivery system so that it monitors, protects and automatically optimizes the operation of its interconnected elements, from the central and distributed generator through the high-voltage network and distribution system, to industrial users and building automation systems, to energy storage installations and to end-use consumers and their thermostats, electric vehicles, appliances and other household devices. Smart grid is the integration of information and communications system into electric transmission and distribution networks [2].

The smart grid will be characterized by:

- A two-way flow of electricity information to create an automated, widely distributed energy delivery network. Figure 1 shows the flow in smart grid framework by US Department of Commerce [3].
- It incorporates into the grid the benefits of distributed computing and communications to deliver real-time information and enable the near-instantaneous balance of supply and demand at the device level, with certain standards [4].

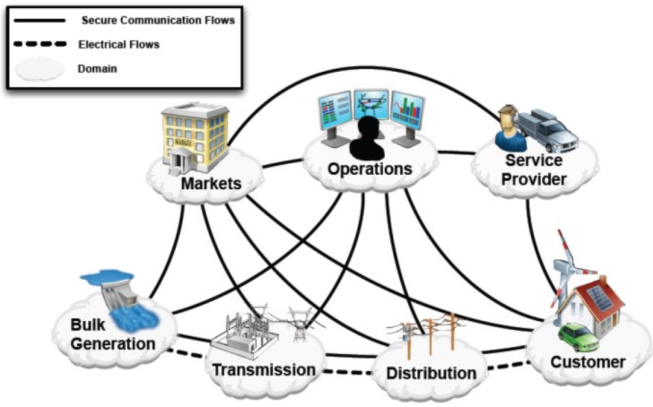

Fig. 1. Smart Grid Framework. Source: US-NIST Framework and Roadmap for Smart Grid interoperability Standards, Release 2.0

The smart grid enables the more efficient management of consumers' end uses of electricity as well as the more efficient use of the grid to identify and correct supply demand-imbalances instantaneously and detect faults in a "self-healing" process that improves service quality, enhances reliability, and reduces costs [5].

II. Smart Grid Initiative

Different countries have different problems and strategies in smart grid implementation, as explained in [2], [6], [7] and [8]. In Indonesia, Task force of Indonesia Ministry for Energy and Mineral Resources has identified key points of Indonesia smart grid initiatives as follow [1].

A. *Objective of Smart Grid Initiative*

- Higher customer satisfaction: the combination of lower costs, improved reliability and better customer control will raise satisfaction among all types of customers (residential, commercial, industrial, institutional).
- Improved reliability: smart grid will reduce and shorten outages and improve the quality of power.
- Shorter outages: the incorporation of advanced sensors and measurement, communication networks and smart systems will allow an unprecedented degree of system visibility and situational awareness of the electric power system. Smart grid will result in shorter outages through its "islanding" and "self-healing" features.
- Consumer's energy/cost savings: as pricing becomes more transparent and is aligned with the underlying economics of generation and distribution, customers' decisions to save money will benefit society as well.
- Highest security: security will be incorporated into the design of the smart grid and will require the implementation of practices and procedures by individual stakeholders. In this way, the physical and cyber security risks can be managed to the highest standards possible
- Timely renewable: smart grid is the enabler of more renewable energy. Its development will allow for the timely incorporation of these sustainable sources of power in a user-friendly, cost-effective manner.

B. *Problems of Consumer Condition*

- Very few houses and building which have energy efficiency awareness.
- Consumers are uninformed and no participative with power system.
- Limited data communication capabilities on installed equipment. Smart meters only installed on new and large industrial consumers.
- Limited opportunities for consumers to take alternative energy sources.
- Cost or tariff increase will become a sensitive issue, compared with other issues e.g. privacy and RF safety [9].

C. *Problems of Electricity Providers*

- Lack of provider owned communication infrastructures. Other's communication infrastructure may available, but there will be additional cost.
- Advance Metering Infrastructure (AMI) is an expensive investment for large number of existing consumers.
- Still dominated by central generation. Many obstacles exist for distributed energy resources interconnection. Unsteady supply from renewable energies (solar, micro hydro) for large demand of electricity.
- Limited wholesale, not well integrated, and non-competitive electricity market, which based on regulated government pricing policies and regulations.
- Still focus on outages, slow response to power quality issues.
- Lack of integration between operational data with asset management.
- Power system only mainly responds to prevent further damage. The focus is on protecting assets following fault.

III. Consumer Partcipation for Smart Grid

The above identification shows that consumers are not participative with power system. For smart grid implementation, consumer should be informed and involved.

A. *Form of Participation*

The possible areas of participation are those which consumers have right and authority to take part. These are:

- Make them and their house or buildings have energy efficiency awareness.
- Add smart metering device which has capability to collect data and report to electricity provider without interfering existing provider's meter.
- Take other alternative source of energy, such as solar energy, to be used on certain time and condition, like the peak time of electricity consumption (6:00 pm to 10:00 pm).

Furthermore, the expensive investment problem of electricity provider for Advance Metering Infrastructure (AMI) also can be solved through consumer's participation.

B. *Participation Requirements*

Considering that consumers participate for smart grid initiative by their own cost, then some requirements for success implementation should be identified.

1. Benefits

   Consumers should get true benefits for the participation. The true benefits can identified from what they need in the existing system now.

- There are two types of meter in population, the prepaid meter and postpaid meter. Nowadays, only prepaid meter provided for Indonesia residential and commercial consumers. Postpaid meter is only for large industrial consumers. Especially in prepaid meter system, consumer need to be alerted the time to buy refill token, long enough before the critical time to refill, and via the easiest way, such as SMS (Short Message Service) to consumer's mobile phone. Existing meter does not have that feature.
- Consumers need to be alerted on power quality problem, to make quick action before damaging electronic equipment and immediate report to provider.
- Consumers need to know the statistical data of monthly consumption for previous months, so they can analyze and make improvement in energy consumption.
- Consumers may need to be able to schedule the switching to alternative source of energy they have such as solar energy, so it switch automatically at time desired. Then, consumers can get incentive based on a smart tariff scheme because of their participation [10].

A device which provides above benefits, and able to collect data and report to electricity provider on consumers permission, is needed for smart grid initiative.

2. Cost

The cost of device acquisition and operation, for consumer to participate in smart grid initiative and get benefits, should be affordable. It will be relative to consumer condition, but it can be assumed that device acquisition cost should not more expensive than consumer cost to register as provider's customer (install new metering), and device operation cost should not make monthly cost increase significant.

3. Technology used

- A low cost and low power embedded microcontroller, sensor, and communication module are required.
- Communication to provider's data server via internet is recommended because the common availability of IP network infrastructure.

In Indonesia, there are two common internet services for residential, ADSL and GSM/GPRS service. GSM/GPRS gives more advantages in this application because:

- It already covered wide area.
- It support personal alert via Short Message Services (SMS) at low price.
- It supports internet data services for device communication to provider's data server. GPRS is adequate for low bandwidth need, at low and competitive price.

IV. Design and Implementation

Some device designs already proposed to support smart grid implementation, as explained in [11], [12], and [13]. We propose a design and implementation of consumer device that focus to meet consumer benefits and cost constraint, especially for Indonesia smart grid condition, as follow.

A. Network Diagram of Communication

Figure 2 shows network diagram of communication. Device will communicate to user (consumer) via SMS, to send alert or requested information. Blackout and power quality problem should generate SMS alert to user. On user permission, device also can submit consumption data to electricity provider's data server via GPRS on daily or monthly basis. Data will be identified by customer ID, configurable by consumer, and filtered in server. Additional security mechanism can be implemented in communication.

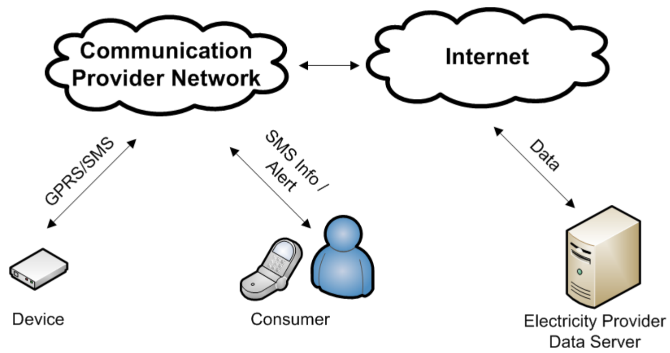

Fig. 2. Network Diagram of Communication

B. Block Diagram of Device

Figure 3 shows block diagram of device. A low power microcontroller can be used as central processing. It schedules data acquisition of electrical voltage and current from sensor, calculates the consumption, accumulates and saves data to its EEPROM periodically based on Real Time Clock (RTC). Automatic SMS notification to user and data submission to electricity provider's data server, are sent via GSM/GPRS module. Device is also equipped with battery backup to maintain its power in electricity blackout condition.

Relay and contactor are optional to use for users who has alternative source of energy to schedule. User interface is provided. Some user buttons and mini LCD display are provided for user configuration activity. User can know current prepaid account status and current month energy consumption. Some menus are provided to change user mobile phone number for SMS notification and set the schedule of alternative source of energy.

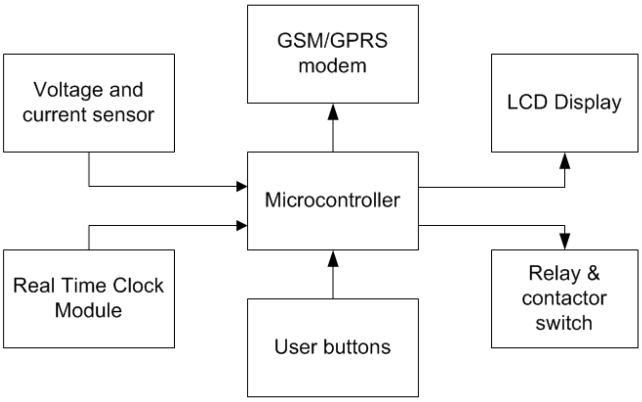

Fig. 3. Block Diagram of Device

C. *Implementation*

Figure 3 shows a prototype implementation of device with technical specifications in Table I. Design uses a low cost microcontroller, voltage and current sensor, GSM/GPRS module with internal RTC, LCD text display, and Lithium Ion battery backup.

Fig. 4. Device Prototype

TABLE I. PROTOTYPE SPECIFICATIONS

Category	Specification
Controller	8 -bit microcontroller AVR Clock Speed: 16 MHz Operating Voltage: 5V 14 Digital I/O Pins (GPIO) 6 Analog Input Pins 10-bit ADC resolution (ADC) 32 KB Flash, 2 KB SRAM, 1 KB EEPROM 1 USART
Sensor	SCT013 30A
RTC	SIM900 internal RTC
Modem	SIM900 GSM/GPRS modem
Display	LCD character 16x2
Battery	Lithium Ion 6000 mAh 5V

Acquisition cost and operational cost of device are provided in Table II.

- The acquisition cost of device is calculated based on retail price of modules and components in 2013.
- The operational cost of device is calculated based on lowest price of service package from communication provider in Indonesia market 2013.
- The cost of new electricity installation as comparison is based on the PLN (Indonesia State Electricity Company) price for residential consumer 1300VA in 2013.
- The cost of average electricity cost as comparison is based on the BPS (Indonesia Center of Statistic Body) survey for residential consumption in big cities in 2012.

TABLE II. COST ANALYSIS

Type of Cost	Cost
A. Acquisition cost of device	Rp 840,000
B. Operation cost of device	Rp 25,000 / month
C. Cost for new meter and electricity installation for residential consumer 1300VA	Rp 975,000
D. Average electricity cost of residential consumer 1300VA	Rp 250,000 / month
Percentage A from C	86%
Percentage B from D	10%

From the case above, it can be expected that acquisition cost of device will not more expensive than consumer cost to register as provider's customer (install new metering device), and operational cost of device will not make monthly cost increase significant.

V. CONCLUSION

The consumer participation for smart grid initiative can take smart metering device as early step for energy efficiency awareness. Device can be designed to give additional benefits for consumers at affordable cost, to get consumer's interest to be involved in smart grid initiative. Refill token notification, power quality alert, statistical data usage, and support for optional source of energy are main functionality requirements for Indonesia customers.

A low cost microcontroller based prototype device has been made to observe design functionality and cost occurred. The acquisition cost and monthly operational cost of device are taken as the observed parameters. Design and prototyping experiment show that the functionality requirements can be achieved at affordable cost defined.

Further work can be taken to improve device functionality and continue overall system development in next stage implementation of smart grid system.

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