Integrated Management of Smart Utilities inside Smart Cities

Francisc Demeter
POLITEHNICA University of Timisoara, Power Systems Department, Timisoara, Romania
Email: demeter@elecon.ro

Flaviu Mihai Frigura-Iliasa and Marius Mirica
National Institute for R&D in Electrochemistry and Condensed Matter, Timisoara, Romania
Email: flaviu.frigura@upt.ro, miricamc@yahoo.com

Lia Dolga and Hannelore Filipescu
POLITEHNICA University of Timisoara, Mechatronics Department, Timisoara, Romania
Email: lia.dolga@upt.ro, hannelore.filipescu@upt.ro

Madlena Nen
Military Technical Academy, Management Department, Bucharest, Romania
Email: madlenanen@yahoo.com

***Abstract*—The explosive development of urban areas is a great challenge, but also a great opportunity to develop technologies and services that will profoundly change the way we see and perceive our society. The exponential improvement of our electronics, telecommunication or information technologies, and the lower cost of production, allows us to solve complex challenges and bold leaps in the development of urban areas. This article proposes a solution for integrated utilities, addressing the challenges that come with large telecommunication, water, gas and electricity networks, in order to provide services at a low, reliable and sustainable price. For the future, it is expected that millions of distributed, storage and management power generation systems, but equipped with autonomous intelligence and automation to increase the economy, sustainability, reliability and security of technical-municipal networks.**

***Index Terms*—integrated utilities, smart grid, information technologies, automation**

I. Introduction

Utilities are following the trends stemming from the deregulation and privatization of energy produced from renewable sources, the growth of the industry sector and public sustainability consciousness.

We are living a period in the history of mankind, where data and information become the key to long-term success. The purpose of this paper is to identify, through our research, a way to eliminate many of the functional and organizational barriers that exist between utilities and customers [1].

A major issue in this relation is that customers have no control over consumption, except for connection or disconnection of devices, and no possibility to fully generate local utilities for the household. This situation has begun to be improved at the same time as developing intelligent shareholder concepts, intelligent metering and smart grids.

We will offer a simple, practical vision, and, in principle, a rethinking of all utilities business and housing utilities to ensure continuity, reliability and safe operating conditions for all customers.

We will detail below all these concepts.

II. Integrated Intelligent Utilities

We will define all main concepts about data flows in the integrated utilities.

A. Unidirectional Data Flow Process

The first step will be to redefine the data-based process. Understanding the chain is the key to switching from regular utilities to smart utilities

The principle of one direction data-driven flow chain is presented in Fig. 1.

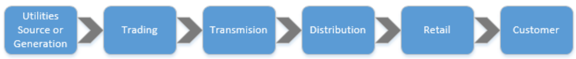

Figure 1. The one direction data-driven flow chain

Until now, the flow has only one meaning and has been defined by functions. The first link between the "Utilities Source" or "Generation" and "Trading" is the most important, it has the greatest impact on utilities prices. This comes from the fact that the largest margin in the utilities price is made by the generation cost.

It consists of the cost of the primary energy source (eg. gas, water price, coal, etc.), investment in the generation / installation and maintenance costs and personnel [2].

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Also, the price is dictated by trading and well-known market rules based on supply and demand. The third element of the chain is the transport system, which has a lower impact on utility prices, but has an important role in representing critical infrastructure in the utility system. Typically, there is only one network operator and may have an impact on price depending on the level of development and maintenance costs of the utility system.

Distribution has the lowest percentage in utilities, due to the fact that there is only maintenance and does not require much staff. In a nutshell, the customer-merchant chain (utility provider) is very rigid. The customer is captive and has no alternatives to reduce costs or there are no feasible solutions, being contractually obliged to take up a certain amount of energy to consume even if the household has alternative sources of energy.

The key description for a unidirectional chain is rigid and uninteresting for the customer's real needs, although it contains a complex interconnection system between the market, transport and distribution, clearly ignoring the need for distributed energy sources at the distribution level.

The unidirectional chain must be transformed into a bi-directional chain based on interoperability, like the one presented in Fig. 2.

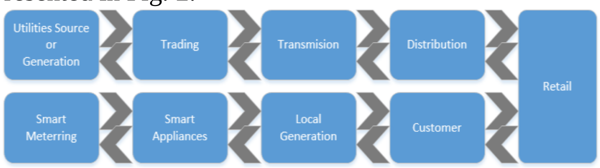

Figure 2. Note how the caption is centered in the column

B. Multidirectional Data Flow Process

Through the bidirectional chain it will impact the utility price but will make the customer the center of the system by replacing the system itself.

Considering that the customer will have smart devices and local power generation solutions, he will be able either to isolate the system, or to make a distributed generation node, or he can be a smart consumer himself.

We can say that the last three pieces of the chain can be taken as one - a smart consumer.

The retail will have two ways of negotiating. One with a traditional trading market and one with smart consumers who want to produce energy and who will inject directly into the distribution system at a good price or simply to reduce the cost of the monthly invoice. In this way, the traditional energy generated, transported and the trading market will be in direct competition, which will have a positive impact on all intelligent and traditional customers, and, this will lower the price of utilities. It will also have a good positive impact on the environment, knowing that, worldwide, large energy producers have approx. 60% of the energy produced from non-renewable fuels (coal, gas, diesel).

On the other hand, domestic producers generate more than 80% energy from clean (wind, solar, hydro) sources.

By comparing the two chains, the advantages are clearly on the two-way chain:

- Increases competitiveness on the trading market;
- Has high impact on the marginal cost of energy production;
- The client becomes the center of the system;
- Has low environmental impact, increasing the renewable source percentage in distributed energy sources.

To be more detailed about how the proposed system will work, in our research we started from the hypothesis that commercial or civil, that would be able to consume and produce [2].

It is well known that there are several ways to reduce utility costs by generating local energy, intelligent appliances and intelligent metering.

C. The Functionalities of the System

Demand is the first step and one that will make us consider whether a customer can implement this and whether or not it is possible [3].

This will be decided by the analysis of:

- Power consumption
- The cost of implementing smart utilities
- Implementation cost and other energy sources (if necessary).

After analysis, if we have an eligible customer, smart metering will be implemented, by using a Customer Relationship Management (CRM).

The main intelligent metering interactions are achieved with SCADA systems and billing through CRM. Fig. 3 will detail these principles.

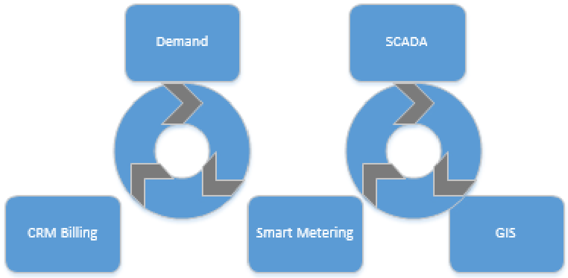

Figure 3. The smart metering interactions.

SCADA is the abbreviation for supervisory data acquisition and acquisition systems and is a system designed to be used in the industrial environment for remote monitoring and control to operate different industrial protocols and communication channels. This system will deliver to CRM all the data to be analyzed in order to optimize the price of energy at the trading market and to influence generation and transport [1].

GIS is a technology used in all activities that require manipulation and analysis, generate and present all types of geographic spatial data. In our context, this will be used in an integrated system with the surveillance system to provide accurate data for the inter-team to increase continuity in utility distribution.

The surveillance system will be used to track system stability and reliability. In case of problems with generating or managing smart metering using GIS, an unlikely disruption of utilities will be treated as a matter of urgency by the distribution maintenance department. Depending on the incidents, this could affect the monthly invoice or not.

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On the other side of smart metering, CRM billing provides a clear view of consumer production maintenance, data analysis, with the aim of providing quality data and constantly optimizing production costs and energy prices through setting up a system by recalculating demand and supply every time.

As a result of the proposed chain, it will have the following repercussions on utilities:

- Active distribution control and low voltage network becomes a necessity;
- Distribution and management through its own utility application;
- The energy market becomes more flexible and dynamic;
- High battery technology advance.

D. System Overview

All these changes within the utility chain will be reflected in IT management and data systems. They will begin to play a critical role in utilities infrastructure and will bring much of their business value. Business model for utility companies will not change overnight, but they will need to be open to interoperability between IT systems and utilities infrastructure [4] in order to increase agility and performance and meet basic demands such as:

- Detailed consumption of utilities similar to those in banking systems and mobile telephony systems;
- Optimizing home and workplace consumption by setting the room temperature to await your arrival;
- Flexible prices by season and time of day.

III. Examples and Case Studies

The proposed solution is focused on energy solutions, utility delivery processes, and solutions ranging from smart metering, intelligent networking, energy trading, large data, CRM, and billing in order to solve the utility chain.

We have a look at the interactions that take place between these technological areas, where the application of interoperability management principles and real-time data analysis will help us discover new levels of utility networks for both home and corporate users.

Smart meters will be used to obtain:

- The correct invoice, which will reflect a clear picture of generation and consumption
- Understanding consumer behavior
- Rapid switching between gas and electricity based on dynamic costs or switching from energy consumption to production and injection into the grid.
- Customer data has innovative energy pricing so that suppliers can create a cheap priced calendar for use during the empty period.

Through research we have established a model that will help us move from utilities to smart utilities.

For our study we considered two types of consumers, smart home appliances and smart meters.

The intelligent appliances considered for the study will include the following additional components and design changes compared to standard home appliances:

- Standard Network and Interface Protocol Network Connection;
- Required control systems;
- Requesting and response components for energy storage (electricity, heat, cold), measurement and transducer circuits;
- Programming the control system to take into account relevant appliance model changes for the consumer model;
- Additional power sources to meet voltage and power requirements by electronic components in a standby mode to comply with ecodesign requirements for network waiting and other regulated requirements.

Devices will need very limited additions of electronic circuits and other components, due to the fact that in most cases smart devices already have network communication [5], therefore the additional impact on appliances to provide connectivity and intelligent functionality on resources and energy used for the production phase is assumed to be marginal and is not taken into account further.

The case study of this article will be related to an average pattern of consumption in Europe.

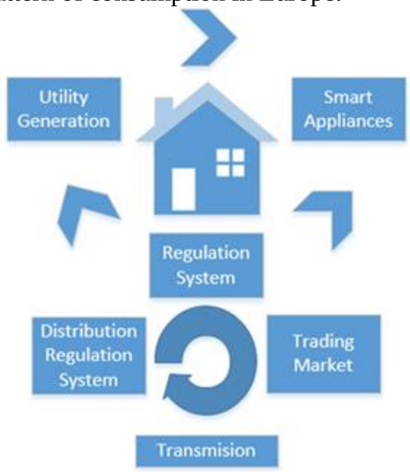

Figure 4. Energy regulation models.

This assumption is made on an average household located in a climatic zone with 4 seasons, with intelligent utilities and alternative energy production and with the next energy consumption, described in Fig. 4.

Fig. 4 shows the main logical component of the control system that has to balance the demand between the transmission system and the distribution system with distributed energy sources. The regulator in the control system is a complex function that must continually calculate the constraints between the transport-generation activities and the distributed-consumption generation.

The system will push the results once in the CRM billing system, which is part of the regulatory system and the trading market, to balance the demand-side market.

The consumption data is revealed in Table I and the average consumption limits (upper and lower) are shown in Table II and Table III.

TABLE I. COMPONENTS OF THE CRM BILLING SYSTEM

Module Name	Description
Smart appliances	Dishwashers Washer-dryers Radiators Boilers Heat pump Air conditioner Lightning
Energy generation	Solar panel Windmill Heat pump
Trading market	Utility market CRM Billing system
Regulation system	The assembly of regulations systems that are based on laws and regulations in the utilities domains
Distribution system regulations:	Contains all the components to get the utilities from the transmission system to the consumer: physical (lines, stations, SCADA system)
Transmission	Made out of transport lines substations dispatch and energy management systems

TABLE II. HIGHER CONSUMPTION LIMITS

Utility	Component	Average Consumption	Unit
Heating	Radiators	11800	kWh\year
	Heat pump	2200	kWh\year
Hot water	Boilers	4000	kWh\year
	Solar heater	0 (solar powered)	kWh\year
Cooling	Air conditioner	1100	kWh\year
	Heat pump	300	kWh\year
Other	Lightning	180	kWh\year
	Dishwashers	240	kWh\year
	Washer-dryers	280	kWh\year
	Other	100	kWh\year

TABLE III. LOWER CONSUMPTION LIMITS

Utility	Component	Average Consumption	Unit
Heating	Radiators	8800	kWh\year
	Heat pump	1700	kWh\year
Hot water	Boilers	1500	kWh\year
	Solar heater	0 (solar powered)	kWh\year
Cooling	Air conditioner	300	kWh\year
	Heat pump	600	kWh\year
Other	Lightning	180	kWh\year
	Dishwashers	240	kWh\year
	Washer-dryers	280	kWh\year
	Other	100	kWh\year

The main inputs and outputs for each component are presented in Table IV. The output of the model will be treated by the distribution control system and will become an entry for the CRM billing system.

The CRM will analyze this data and give input for the triple generation-transmission-trading and will ultimately optimize the utility price, balancing the demand for the offer.

TABLE IV. MAIN POWER CONSUMERS

Component	Input	UI	Output
Radiators	Power consumption	kWh	Ambient temperature
Heat pump	Power consumption	kWh	Ambient temperature
Boilers	Power consumption	kWh	Hot water temperature
Solar heater	None		
Air conditioner	Power consumption	kWh	Ambient temperature
Heat pump	Power consumption	kWh	Ambiental temperature
Lightning	Power consumption	kWh	Daylight savings
Dishwashers	Power consumption	kWh	Consumer habit
Washer-dryers	Power consumption	kWh	Consumer habit
Other	Power consumption	kWh	Consumer habit

The inputs and outputs of the transmission-generation-trading of energy are presented in Table V.

TABLE V. MAIN CONSUMING INPUTS/OUTPUTS

	Input for CRM	Output	Input for triplet
Utilities distribution	Electricity consumption	Peak Demand	Production threshold
	Gas consumption	Peak Demand	Delivery threshold
	Hot water	m^3/h	Energy input
	Water	m^3/h	System parameters

IV. CONCLUSIONS

We proposed a solution trough out integrated utilities solutions, to the challenges and complexities that come with large networks of utilities such as telecommunication, smart grid and water utilities in order to have economical, reliable and sustainable services.

The CRM Billing will offer a clear view of the consumption production maintenance actions, data analysis in order to provide quality data and permanent optimization of cost production and energy price, trough that closing the system flow by recalculating at each moment of time the demand and the offer.

This model is well suited for households located in temperate climate, with efficient energy use. It could be improved by taking in consideration more consumers and more utilities, for larger consuming units.

It is a proof of concept already applied in the utilities management of a small block of flats located in Timisoara, Romania, in order to optimize all power fluxes inside the consuming unit.

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Francisc Demeter was born in 1965 in Romania. He graduated the Faculty of Electrical and Power Engineering, from the POLITEHNICA University of Timisoara, in 1989 as Power Engineer. He is the co-founder of ELECON Plus, the main power construction company in Arad, Romania, and he is also a PhD student at the POLITEHNICA University of Timisoara, Romania. His research is about cables maintenance.

Flaviu Mihai Frigura-Iliasa was born 1975 in Romania. He graduated the Faculty of Electrical and Power Engineering, from the POLITEHNICA University of Timisoara, in 1998 as an Electrical Engineer. He is an Assistant researcher at the National Institute for Electrochemistry and Condensed Matter in Timisoara, and also, an Assoc.Prof.Dr. at the POLITEHNICA University of Timisoara, Romania. His research interests are in the area of High Voltage Equipment, Power Apparatus and Advanced Electronic Materials.

Marius Mirica was born 1975 in Romania. He is a researcher at the National Institute for Electrochemistry and Condensed Matter in Timisoara, director of the PV Lab. His research interests are in the area of Advanced Electronic Materials.

Lia Dolga was born in Romania. She graduated the Faculty of Electrical and Power Engineering, from the POLITEHNICA University of Timisoara, as Electrical Engineer. She is a professor at the Mechatronics Department from the POLITEHNICA University of Timisoara, Romania. Her research interests are in the field of CAD applications and robotics.

Hannelore Elfride Filipescu was born in Romania. She graduated the Faculty of Mechanical Engineering, from the POLITEHNICA University of Timisoara, as Mechanical Engineer. She is a lecturer at the Mechatronics Department at the POLITEHNICA University of Timisoara, Romania. Her research interests are in the field of CAD applications and robotics.

Madlena Nen was born in Romania. She e is a lecturer at the Military Technical Academy in Bucharest, Romania, at the Management Department. Her main research domains are related to production optimization, organizational politics and any management issues.