Data Model for Electricity Consumption Management

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The power management system targets three major sectors: energy production, market trading and energy consumption. Energy consumption management is based on optimization models and methods that are implemented with actual system data. In order to identify these methods we have analyzed a series of related papers on optimizing energy consumption.
As a result, in this paper, we present the improvements that we made on the data model for electricity consumption approach from SMARTRADE project.

Keyword: *electricity consumption, renewable energy, optimization methods*

1 Introduction

The management of electricity consumption implies making the right decisions for energy consumption optimization in the context of demand-management mechanisms. All consumption optimization models and methods use industry-specific data. In this context, an important role in the management of electricity consumption has its way of organizing the data. It is very important that the data model contain accurate, consistent, relevant data, real-time links and fast access to real-time decisions.

2. Related works on energy consumption optimization

Energy consumption management is based on optimization models and methods that are implemented with actual system data. In order to identify these methods we have analyzed a series of related papers on optimizing energy consumption.
In the paper [1], the authors present an analysis of models and methods for energy consumption optimization for residential users in the context of demand-management mechanisms, which are used to reduce peak demand or to avoid emergency cases.
In the paper [2] the authors make a review of various concerns about optimization methods and highlight the fact that since the creation of a renewable energy structure entails very high costs in terms of design and long-term planning of energy systems, it is very important to be able to select the best alternative between different renewable energy systems.
An important issue is the planning of renewable energy systems at Community level, which consists in formulating local energy consumption policies, developing energy resource and energy allocation patterns, economic development and energy structure as well as analyzing the interactions between economic cost and safety in power supply.
In order to obtain solutions to ensure the allocation of energy resources / services and the expansion of the desired capacities, the minimum system cost, maximum system reliability and maximized energy security, some authors have opted for the application of interval linear programming, chance-constrained programming, and mixed integer-linear programming.
The paper [3] presents a non-linear programming model developed for a typical factory, which presents the optimal values and times for the electrical energy

consumption based on doing activities and operations in factory.

In [4] it is developed a distributed optimization method by which they calculate optimal consumption levels in an iterative manner and the intermediate results obtained are used by smart meters to calculate probability distributions of start times for tasks. Using these distributions, smart meters can quickly plan their tasks.

The article [5] analyzes the minimization of power consumption in wireless systems where nodes operate on battery and [6] makes a review on optimization modeling of energy, as Deterministic Optimization Modeling, Inexact Optimization Modeling, Model-Based Decision Support Tools.

The studies [7], [8] and [10] propose multi-objective optimization methods for developing energy systems using primary energy consumption and initial cost. [9] proposes a long-term dynamic multi-objective planning model for distribution network expansion along with distributed energy options which, using an immune genetic algorithm-based (I-GA) algorithm, optimizes costs and emissions by determining the optimal schemes of sizing, placement and dynamics of investments on distributed generation units and network reinforcements over the planning period.

The paper [11] analyzes and synthesizes energy-optimization methods using either cloud-based video surveillance systems or video surveillance systems in general. The paper highlights the limitations of the application of the methods in the cloud video surveillance system due to the architecture and the energy consumption characteristics of the system.

In the dissertation thesis [12], the author develops a method to minimize the energy consumption of production equipment using a mathematical model for multi-objective problems on single or parallel machines, to minimize energy consumption in production planning. The method uses a genetic algorithm, greedy randomized adaptive search procedure and meta-heuristic hybrid approaches to obtain sets of reasonable approximate solutions in reasonable time used in decision-making on production planning.

3. Electricity management system architecture

The power management system targets three major sectors: energy production, market trading and energy consumption.

The informatics prototype will be developed in a modular manner in order to support a flexible and scalable implementation. Thus, the proposed models (Figure 1) are:

- Electricity Consumption (EL) that aims to provide a demand response solution with load forecast (LF), load profiles (LP) and load optimization (LO) models;
- Electricity Generation (GEN) that aims to increase the actual forecasting accuracy through generation forecast (GF) model and also to provide a better generation management through generation optimization (GO) model;
- Market Trading (MT) will implement market trading models (MTM) and simulations (MS) to provide a decision support system for market trading activities;
- Analytics & BI (ABI) aims to provide a friendly, interactive and flexible interface for analysing the Key Performance Indicators (KPI) by accessing a web portal with reports, charts and dashboards.

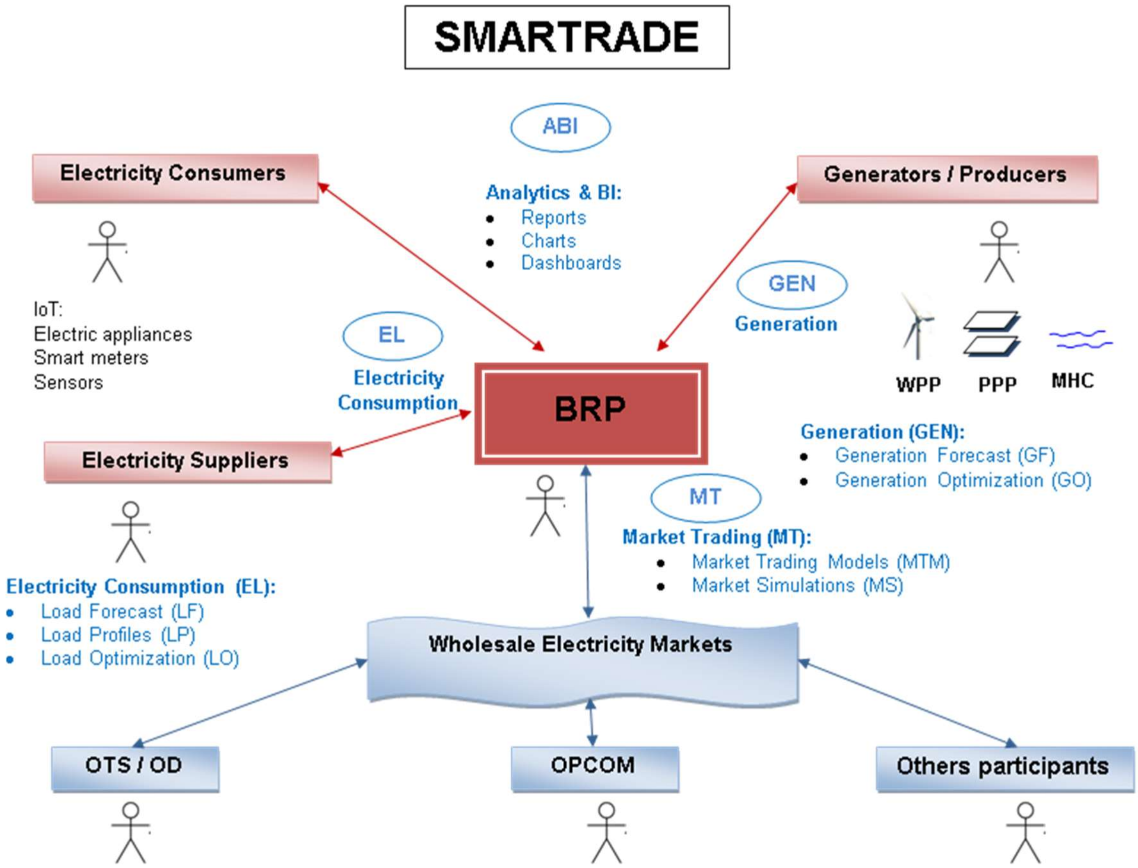

Fig. 1. Electricity management system

We designed the systems' architecture based on three levels: data, models and interfaces. The complete architecture is represented in Figure 2

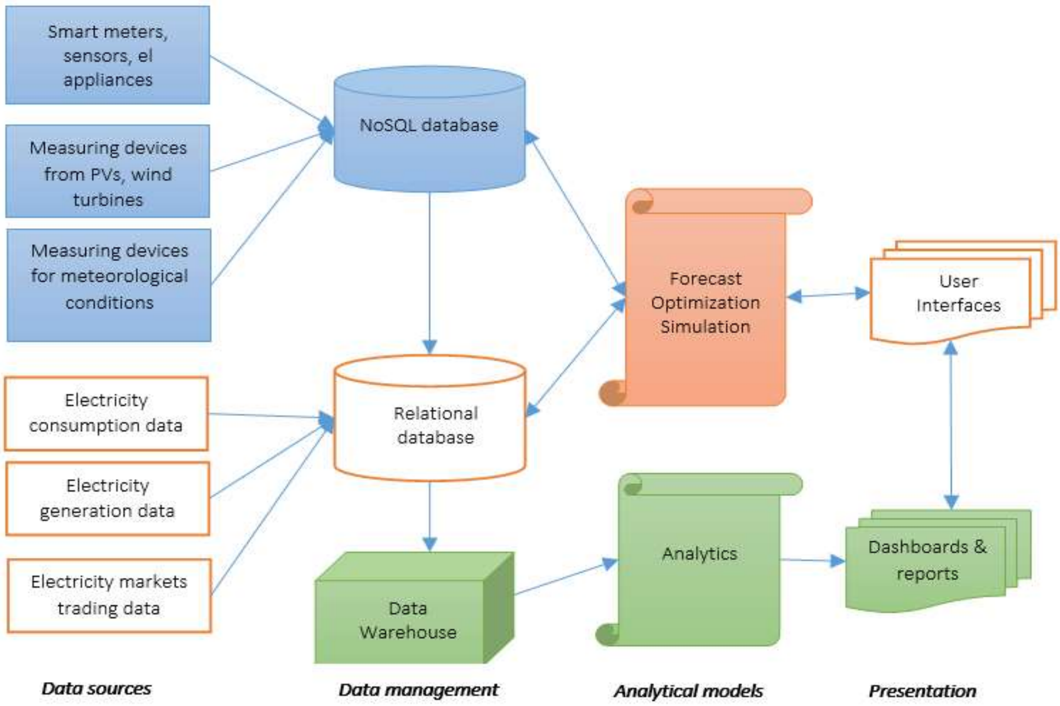

Fig. 2. SMARTRADE proposed architecture

4. Identifying data and their relationships in the electricity consumption management system

The data model involves identifying data collections, establishing relationships, identifying attributes, and integrity constraints.

In order to develop the database schema for each module, we design the activity diagrams (Figures 3-6) and also revised the data models to support the forecasting and optimization models.

The main activities identified in the electricity consumption model are as follows:

- CO: The main actors, consumer and supplier, will negotiate consumption and generation on the place of consumption. The consumer accepts tariffs and it is signed the contract. Using the configuration from the place of consumption, the supplier install / configure Meters & Sensors;
- LP: Based on the consumer data, the supplier will select the profiles and the algorithm used;
- LF: Using weather data and historical consumption the supplier will configure the forecast parameters and will select and apply the algorithm. Based on the comparison of the predicted values with actual values, the supplier will send real consumption to the BRP (Balance Responsible Party);
- LO: The supplier configures optimization parameters, which will lead to the optimization results that need to be viewed or adjusted. As a result, the consumer will access and implement the optimized consumption program in order to minimize the costs.

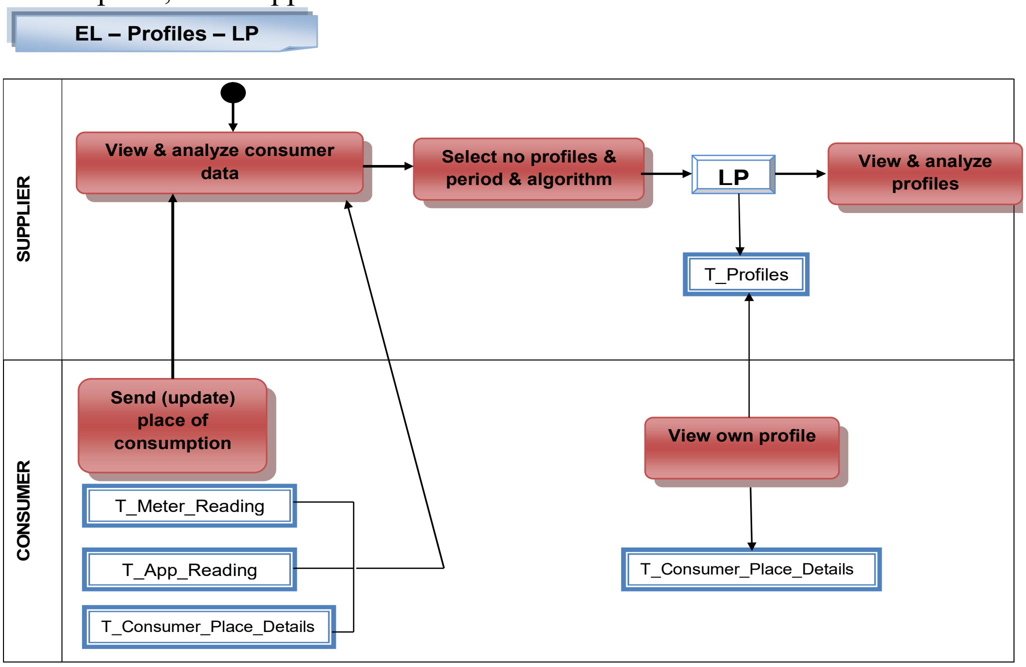

Fig. 3. Activity diagram for Load Profiles (LP)

The activities flow for the **Load Profiles** is detailed in the above figure and consists in the following activities:

1. View & analyze consumer data
2. Select number of profiles & period & algorithm
3. View & analyze profiles
4. Send (update) place of consumption
5. View own profile

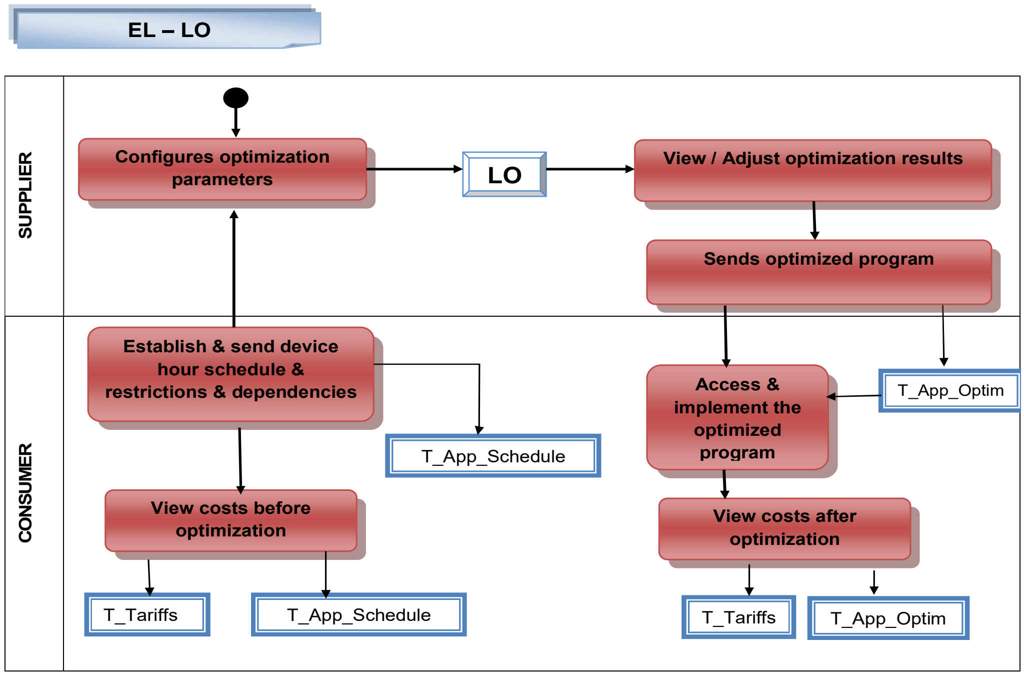

Fig. 4. Activity diagram for Load Optimization (LO)

The activities flow for the **Load Optimization** is detailed in the above figure and consists in the following activities:

1. Configures optimization parameters
2. View / Adjust optimization results
3. Sends optimized program
4. Establish & send device hour schedule & restrictions & dependencies
5. View costs before optimization
6. Access & implement the optimized program
7. View costs after optimization

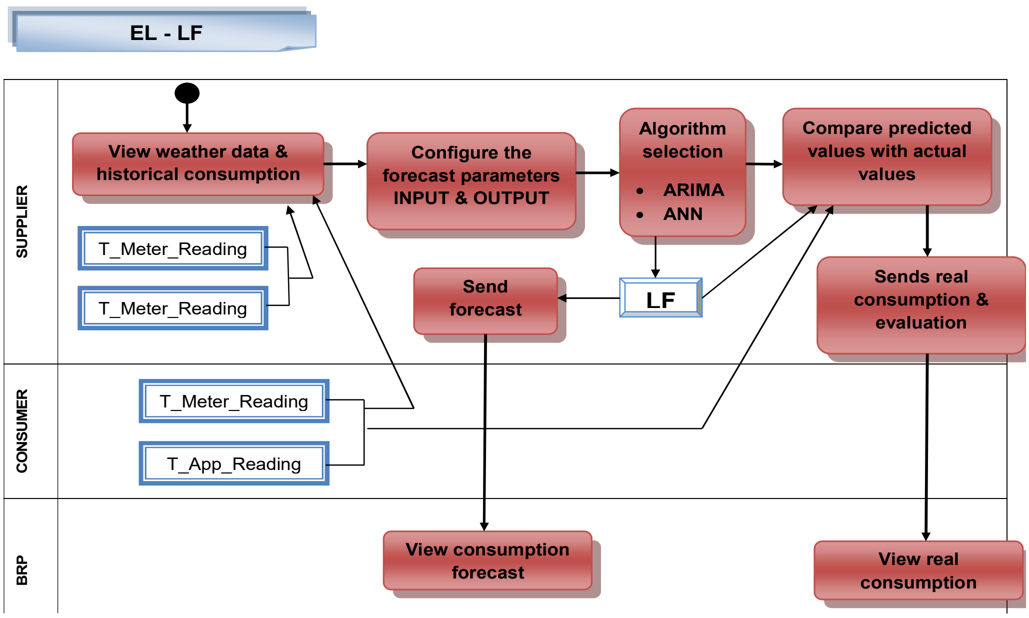

Fig. 5. Activity diagram for Load Forecast (LF)

The activities flow for the **Load Forecast** is detailed in the above figure and consists in the following activities:

1. View weather data & historical consumption
2. Configure the forecast parameters INPUT & OUTPUT

3. Algorithm selection (ARIMA. ANN)
4. Compare predicted values with realized
5. Sends real consumption & evaluation
6. Send forecast
7. View forecast consumption
8. View real consumption

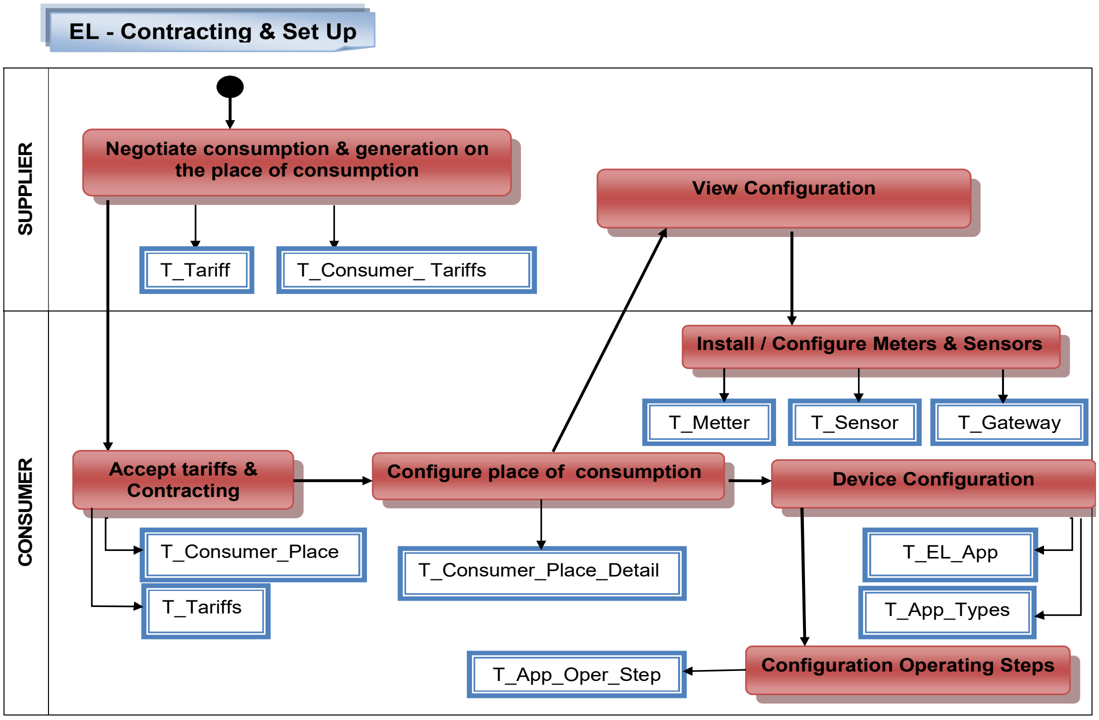

Fig. 6. Activity diagram for Contracting (CO)

The activities flow for the **Contracting & Set Up** is detailed in the above figure and consists in the following activities:
1. Negotiate consumption & generation on the place of consumption
2. Accept tariffs & Contracting
3. Configure place of consumption
4. View Configuration
5. Install / Configure Meters & Sensors
6. Device Configuration
7. Configuration Operating Steps

5. Database schema for Electricity Consumption module

First stage of the data model was detailed in [13] and contains tables initially identified following the system analysis.

In the current stage, we have refined the database, adding new tables or improving the existing ones.

The new tables included in the database are the following:
- T_WEATHER_STATIONS
- T_WEATHER_READINGS
- T_APPLIANCE_OPTIM
- T_APPLIANCE_SCHEDULE
- T_APPLIANCE_OPER_STEP
- T_SENSORS
- T_GATEWAY

Improved EL database schema is represented in the Figure 7.

Fig. 7. Refined database schema

6. Conclusions and future works

In this paper, we have analyzed a series of related papers on optimizing energy consumption and we have proposed some improvements for the electricity consumption data model.

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