A Simulation Tool for Demand Response Programs Implementation

Pedro Faria, Zita Vale

GECAD – Knowledge Engineering and Decision-Support Research Group of the Electrical Engineering Institute of Porto – Polytechnic Institute of Porto (ISEP/IPP),
Rua Dr. António Bernardino de Almeida, 431, 4200-072 Porto, Portugal
{pnf, zav}@isep.ipp.pt

Abstract. The design and development of simulation models and tools for Demand Response (DR) programs are becoming more and more important for adequately taking the maximum advantages of DR programs use. Moreover, a more active consumers' participation in DR programs can help improving the system reliability and decrease or defer the required investments.
DemSi, a DR simulator, designed and implemented by the authors of this paper, allows studying DR actions and schemes in distribution networks. It undertakes the technical validation of the solution using realistic network simulation based on PSCAD. DemSi considers the players involved in DR actions, and the results can be analyzed from each specific player point of view.

Keywords: Demand response, decision support system, simulation

1 Introduction

Demand Response (DR) was expected to significantly grow in the scope of electricity markets, bringing economic and technical benefits to the whole system. However, DR is not being as successful as expected [1]. In this way, the positive impact of DR on power systems and on the involved players' business may be enhanced by adequate tools which are able to simulate DR programs and events, from the point of view of the relevant players. Several tools have been developed to support decision making and validation concerning demand response programs. A list of some tools can be found in [2]. Generally, the existing software aims to assess the cost savings opportunities based on building and load characterization.

DemSi, the DR simulator developed by the authors of this paper, presents several innovative features when compared with other existing tools [3]. One important point is that the other tools deal with specific installations (e.g. commercial or residential buildings) whereas DemSi is able to deal with the application of DR programs to a large set of consumers. Moreover, it uses realistic models that allow to simultaneously take into account contractual constraints and to undertake the technical validation.

DemSi considers the players involved in the DR actions and results can be analyzed from the point of view of each specific player. This includes five types of play-

ers, namely consumers, retailers (suppliers), Distribution Network operatos (DNOs), Curtailment service Providers (CSPs), and Virtual Power Players (VPPs). The analysis can also be done from the point of view of the retailer, of the consumers (both individually or in the scope of a load aggregator) or of the DNO.

Another advantage of DemSi is that it includes a diversity of DR programs. DemSi allows choosing among a large set of DR programs, each one modeled according to its specific characteristics.

2 Computational tools used in DemSi implementation

The development of DemSi has been based on three simulation tools. GAMS – General Algebraic Modeling System – is a computational tool developed to implement linear optimization problems, as well as non-linear and mixed-integer ones [4]. With GAMS the user is concerned only with the formulation of the problem / model. In this way, the difficulties around the modeling of the solving method are suppressed. It is simple to choose from several numeric methods and then comparing the results. The diverse solvers make possible to solve a large variety of problems.

MATLAB is a powerful software of numeric computation that was developed in 1978 by Cleve Moler and is nowadays a property of MathWorks. The main characteristic of MATLAB is the use of matrixes as the basic data structure [5]. As it is an interactive software of high performance, MATLAB is used in several applications in the industry, as well as in academic activities, and has been applied to several problems of science and engineering. MATLAB has toolboxes that allow obtaining the solution for several types of problems such as the ones related with numerical analysis, data analysis, matrix calculus, and signal processing. The user can use the available toolboxes or program functions and routines to solve the envisaged problem.

PSCAD/EMTDC is a simulation tool developed by the Manitoba-HVDC Corporation, dedicated to the system analysis and having electric power systems as the main application area. PSCAD is the graphical interface to the user, while EMTDC is the simulation software. The graphical interface of PSCAD considerably improves the EMTDC usability. It makes possible for the user to build the circuit schematically, to process the simulation, to analyze the results, and to manage the data in a completely integrated environment. An important advantage of PSCAD, which is crucial for DemSi, is the possibility of linking it with MATLAB software.

3 DemSi architecture and implementation

DemSi combines the use of GAMS optimization software and of MATLAB, which has been used to program some of the models. The other models have been programmed in GAMS. PSCAD is used for the electrical network simulation and is connected with the other two software tools.

DemSi is an important tool for DR programs and models analysis and validation, both in what concerns the business and economic aspects and the technical validation of their impacts in the network.

Consumers can be characterized individually or in an aggregated basis. The simulation requires knowledge about load data and about the contracts between clients and their electricity suppliers. These contracts may include flexibility clauses that allow the network operator to reduce or cut the load of specific clients and circuits. On the other hand, the response of each client to the used tariff scheme is also characterized, allowing the analysis of the impact of alternative DR schemes.

Figure 1 presents the DemSi functional diagram. The simulation of a scenario requires information concerning network characterization, consumers' profile, and DR programs models. The gray blocks in figure 1 are the ones that do not change when the conditions of simulation (models, network, etc.) change.

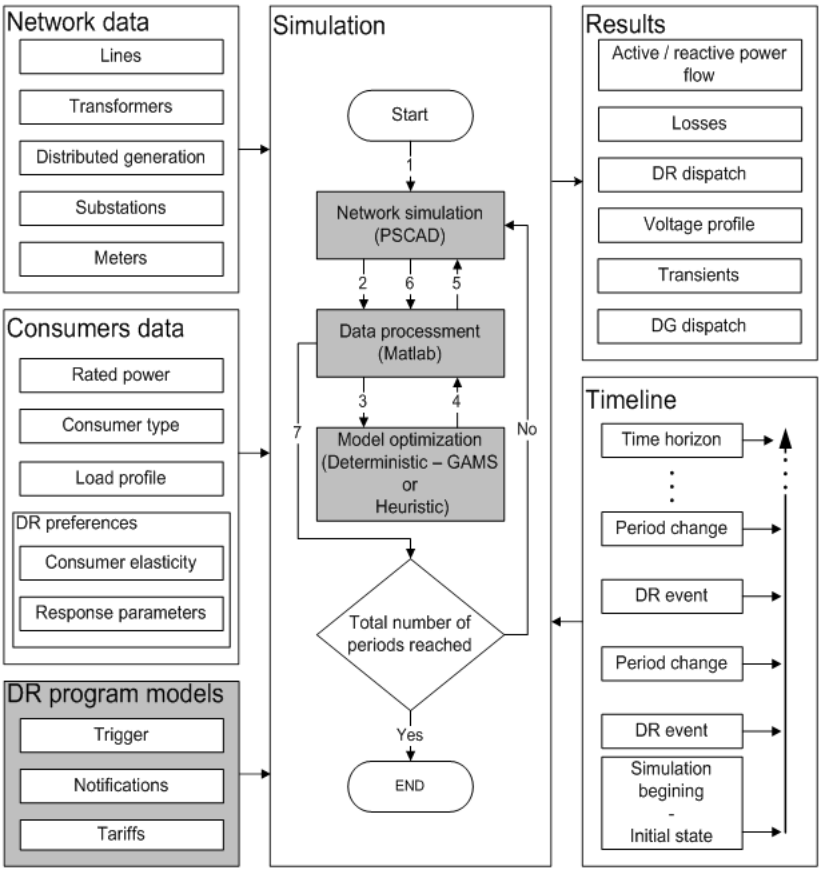

Fig. 1. DemSi functional diagram

PSCAD requires a large amount of parameters for the modeling of the network elements and for the resources connected to it. In this way, the network data (including DG and loads' electrical characteristics) are an important basis for the success of the simulations to be run. The data concerning load response characterization, as well as the event data, are necessary for the DR programs and models simulation.

The simulation timeline is composed by a sequence of periods with a single event or multiple events occurring over time. In the beginning of the simulation, all the variable parameters, including the system voltage, are defined according to the considered initial state. Every change in the system causes instability in the simulation, and therefore some simulation time is given for the system to be in a stable state. After this stabilization time, the network state is saved and the first DR event is simulated. A stabilization period succeeds the DR event trigger; after this, the new state of the system, seen as the results of the event, is saved. This sequence is repeated for the number of periods of the simulation. After saving the results of an event, the network state for the next period is charged.

During the simulation, the different software tools used communicate and transfer data among them. The simulation starts in PSCAD and every time a new network state needs to be charged and/or saved this is done using the MATLAB connection to save/use data to/from Microsoft Excel datasheets. The sequence of software data transferences is represented by numbers in the middle block of figure 1.

4 Conclusions

DemSi, the DR programs simulator presented in this paper, is of crucial importance to enable decision-support by the players acting in DR programs. DemSi presents characteristics that distinguish it from the already existing DR tools, what makes it a valuable contribution to the DR field. A very relevant feature is the realistic technical validation of DR solutions, based on PSCAD, which ensures DemSi applicability to real world problems. Moreover, DemSI provides the means for this analysis to be undertaken from different points of view of several players.

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