Chapter 3

SYSTEMATIC LITERATURE REVIEW

In this chapter, attempting at developing a Systematic Literature Review (SLR) on Decision-making systems that handle uncertainties in Smart Grids, using the guidelines provided by the StArt tool was used [Zamboni et al. 2010]. Such review is divided into three phases. The first, called Search, where some criteria to investigate related work following a defined protocol; the second, called Analysis, where the chosen papers were analyzed and quantified; and the last one, where conclusions obtained from the SLR are presented. Next, each phase is presented.

3.1 PHASE I: SEARCH

At the search phase, the general scope of the research was defined. At this point the research criteria where selected. Those were parameters to choose how a paper would be considered similar to the study or not. Following the protocol, the objective of this research along with the main research questions were defined. Therefore, the search repositories, the standard language, the list of keywords, the search query, the inclusion and exclusion criteria. After defining those, the search could be performed.

The main objective of this research is to find out how uncertainty on load supply or demand have been handled in Smart Grids. Moreover to find which techniques have been given good results on that line of work. In order to guide this study some research questions have served as basis, also referring to the research goal and being defined as follows:

> Given the uncertainty of energy supply and demand, which energy forecast technique can handover accurate predictions to support a Smart Grid Controller on decision-making process?

As a secondary question, the following one was the guide to compose this Systematic Literature Review.

How a Smart Grid Controller could maximize power balancing, given the uncertainty of energy resources or high dynamical demand?

In order to provide some parameters to StArt ranking the searched papers, some expected keywords were defined.

- Decision Support Systems
- Fuzzy
- Smart grids
- Temporal variability
- Energy distribution
- Machine learning
- Strategy
- Uncertainty

English was chosen as the research language, thus, any other work that is not written in that language was discarded.

The search methods used in this SLR were mainly using academic digital libraries search engines, even though manual search had been used to fill the gaps left on the others searches. The chosen repositories were:

- ACM Digital Library [1]
- IEEE Xplore Digital Library [2]

Based on the main question, and specially the secondary question, other questions were elaborated to give support on collected papers analysis stage.

- What is the country of study?
- What is the proposed solution (hypothesis, idea, design)?
- Which dataset is used?
- Does the paper presents use of computational Intelligence on solving Smart Grids energy forecasting?
- Which Computational Intelligence techniques are used?

[1] http://portal.acm.org/
[2] http://ieeexplore.ieee.org/

- Which methods were chosen to aid decision making for Energy Management Systems control?
- Did the results confirms the hypothesis?
- What are the paper's contributions?

Based on the keywords and main question, several combinations of search queries were tried. However, the ones containing more keywords and rounding the scope were too much restrictive, returning a few or none results. Thus, the one that had reach an acceptable amount of results was the following:

> **(((((decision making systems) OR decision support systems) OR knowledge-based systems) AND smart grids) AND uncertainty)**

For this search query some concepts approached in the fundamentals chapter were included. However, even constraining the number of used keywords, the queries had led to very broad results. Hence, some Inclusion and Exclusion Criteria were defined in order to reduce the number of papers, keeping only the ones that were more similar to our research.

The selected criteria were, represented by an (I) for inclusion and (E) for exclusion:

- (I) The works discuss uncertainty treatment on decision making systems.
- (I) The work is about renewable energy sources management control, or load demand control.
- (I) The work involves demand or consumption forecasting for Smart Grids or Energy Management Systems (EMS).
- (I) The Work addresses techniques for uncertainty handling in Smart Grids energy generation or consumption.
- (I) The work involves Machine Learning to solve energy demand or consumption forecasting.
- (E) The work does not address Smart Grid energy control strategies.
- (E) The work does not address decision support for energy management under uncertainties.
- (E) The work relates decision making under uncertainties in smart grids, however the decision is not part of a system.
- (E) The work relates uncertainties in smart grids, however the uncertainties are not specifically on power generation or load demand.
- (E) The work focus on a Hardware technique.

- (E) Despite the work involve decision support for uncertainties for smart grid related systems, it does not use machine learning or a Computational Intelligence approach.
- (E) The work does not involve Computational Intelligence to solve load/supply forecasting for Energy Management Systems.
- (E) It is not a completed work or It is just a short paper, does not presenting a broader model analysis or evaluation.
- (E) Despite the use of a Computational Intelligence technique, the paper does not explore it, that is just mentioned.

3.2 PHASE II: ANALYSIS - SELECTION AND EXTRACTION

After executing the search on the search engines, in total 155 papers were returned as we see in the Table 3.1. However, not all of them could be used. Especially due to the search query has gathered many different concepts, each one having specific niches of research.

At the Selection stage, only the titles and abstract of the 155 papers were read and papers included regarding their titles and abstracts accordance to the defined Inclusion Criteria. At that stage, papers were also discarded if they matched with one or more Exclusion Criteria. As result of that first round, 82 papers were accepted, 70 rejected, and 5 duplicated papers were also excluded.

Table 3.1: Returned results from search query execution.

Repository	**Number of papers**
ACM Digital Library	38
IEEE Xplore	117
Manually	2
Total	**157**

At the Extraction stage, 82 papers were fully read, that means, title, abstract, introduction, and other chapters. However, that stage has worked also as a refinement phase. Some papers were accepted in selection because their titles and abstracts have seemed that the papers were approaching the same subjects of our goals. However, digging a bit more on the introductions, we could notice that some of them did not fit on our criteria. Therefore, they matched with exclusion criteria and have been rejected. As Table 3.2 shows, from 80 papers we have narrowed down to 24. From, those remaining we have extracted answers to the support questions stated in the last subsection.

Analyzing the collected data, an useful information we observed the origin of the accepted papers. The data was summarized on Table 3.3, although the sum of papers pass the number of accepted papers, that is because the Table 3.3 summarizes the participation of countries on research, however a same paper can have authors from different countries. The United States of America represent the major part of the share of the accepted papers, followed by China, what have answered one of our support questions. That

Table 3.2: Number of Accepted papers after each stage.

Revision Stage	**Number of papers**
Search Execution	155
Selection	82
Extraction	24

result also harmonizes with the investments in Smart Grids, on the last decades in the United States.

Table 3.3: List of countries participation on accepted papers

Country	**Number of papers**
USA	9
China	3
Australia	2
Italy	2
Iran	2
Ireland	2
Austria	1
Brazil	1
Cyprus	1
Germany	1
Japan	1
Spain	1
Sweeden	1
Switzerland	1
The Netherlands	1

Another interesting aspect is that the major part of the selected papers are relatively very recent. Their publication years vary between 2011 and 2017, according to Table 3.4. In order to start extracting the required information from the accepted papers, first their reading was prioritized given a score. That score was calculated regarding the number of our keywords present on some parts of the paper. Papers with the highest scores were set to reading priority *Very high*, the ones that had scored in average were set to *High*, the remaining ones were set to *Low*.

This analysis is summarized in the Table A.1, at the appendix section, where the main collected information about the accepted papers is shown. The results of this SLR cope with two main themes: the forecasting of energy generation of consumption; Decision-making processes involving Energy Management Systems. Both themes approach uncertainties related to energy domain. For instance in [Tham e Luo 2013] they have designed and prototyped a smart grid system architecture, that can operate either at the individual household level or at the community level comprising several households. The system make decisions on the quantity and timing of grid electricity to purchase, taking into ac-

Table 3.4: Number of papers by the publication year

Publication Year	Number of papers
2011	1
2013	4
2014	6
2015	6
2016	4
2017	2

count predictors of power demand and supply. In other scenarios, predictors are also used in order to accurately model and forecast the amount of energy generation and demand over time. Particularly, to balance energy demand and supply, developing techniques to effectively manage energy resources and usage in order to adapt to fluctuations [Yu et al. 2015, Paparoditis e Sapatinas 2013].

Other works use some techniques to aid on decision-making. Some of them classify the energy balancing problem as a Markov Decision Problem, solving it with optimization methods [Shann e Seuken 2014, Puggelli, Sangiovanni-Vincentelli e Seshia 2014]. Some other works focus on RES Day-ahead energy forecast, counting with the related uncertainties [Li, Wan e Xu 2016, Dehghanpour et al. 2016].

As result of this SLR, some techniques observed analyzing the selected papers are listed as we can see in Table A.1. The most used techniques were Linear and Stochastic Programming [Puggelli, Sangiovanni-Vincentelli e Seshia 2014], Information-Gap Decision Theory [Soroudi e Ehsan 2013], Monte Carlo Simulations [Quan, Srinivasan e Khosravi 2015]. Along with those, CI techniques were also used, and those are our main focus, such as: Evolutionary methods as Genetic Algorithms [Ferruzzi et al. 2015] and Particle Swarm Optimization [Markidis et al. 2015]; Support Vector Machines [Yu et al. 2015] and Artificial Neural Networks [Quan, Srinivasan e Khosravi 2015, Landa-Torres et al. 2015]; and Fuzzy [Pereira, Almeida e Velloso 2015, Dehghanian, Kazemi e Karami 2011]. Their usage is discussed in the next section.

3.3 PHASE III: PRELIMINARY FINDINGS

In this subsection we succinctly discuss the techniques found on this SLR. The evaluated works have shown how those techniques had aided on decision-making under uncertainty of predicted loads. Despite they were many, some of them were selected for a longer discussion. In this session the discussion tries to answer the SLR's main question, and also foster some insights to support this work's hypothesis.

Optimization has been one of the main goals in the case of robust systems, specially on EMS, due to the high demand of real time decisions. Specially regarding the smart grids, control strategies must yield good responses even on the presence of uncertainty. A technique that has been widely explored on optimization problems is the Linear Programming and its variations as Mixed-integer Linear Programming, Stochastic programming, etc. In [Tham e Luo 2013] They have designed and prototyped a smart grid system architecture, that can operate either at the individual household level or at the community level comprising several households. The system make decisions on the quantity and timing of grid electricity to purchase, taking into account predictors of power demand and supply. The development of an optimization-based decision maker, using Linear Programming or multistage Stochastic Programming, has resulted in a significant reduction of electricity shortfalls, while keeping the cost of purchasing electricity from the grid low.

Another work presents a good alternative to handle historical data from Renewable resources and load demand [Tanaka e Ohmori 2016]. It exploits them as scenarios of RES uncertainties, splitting the time series in intervals by the usage of the K-means algorithm. Those scenarios are used as input for stochastic programming for decision making on Distributed Generation.

Following the optimization line on decision making, Stochastic Modeling has been a very used technique to handle uncertainties. In [Farzin, Fotuhi-Firuzabad e Moeini-Aghtaie 2017] the objective on the proposed approach is to minimize the expected value of microgrid operation costs over the scheduling horizon, considering the uncertainties in load and RES' output-power. The developed model addresses the prevailing uncertainties of islanding duration as well as prediction errors of demand and renewable power generation. Therefore, in [Farzin, Fotuhi-Firuzabad e Moeini-Aghtaie 2017] also a Fuzzy Decision Making method is used for choosing the final schedule among the pareto-optimal solutions. That has shown the possibility in the association of Stochastic Modeling and a Fuzzy Decision Making method, where the uncertainties were captured on the aforementioned Stochastic Model, afterwards handled by the Fuzzy Decision method.

Despite Stochastic Programming be used to handle multiple uncertainties related problems, it presents some drawbacks regarding its high computational burden and requirement of exact distribution of uncertain resources. To handle uncertainties prediction, another method that has been yielding promising contributions is the Robust Optimization [Li, Wan e Xu 2016]. Robust optimization describes uncertainties by sets, so it is independent on preexisting knowledge. Robust Optimization does not need to assume probability distribution, as Stochastic Programming does.

When it comes to smart grid control, reaching the Optimal Power Flow (OPF) is one of the main goals. For achieving that, CI evolutionary methods such as Genetic Algorithms (GA) can give good contributions. This OPF-based scheduling makes use of accurate demand forecasts in order to derive power flow control actions in a predictive way. [Hutterer, Vonolfen e Affenzeller 2013] shows an approximate policy-based control approach where optimal actions were derived from policies learned offline. GA is applied for synthesizing the final policies out of abstract rules where multiple and interdependent policies are learned synchronously with simulation-based optimization. The learning stage is realized using genetic programming, which a synchronous optimization of multiple interrelated policies is implemented using a co-evolution related scheme. In another work, evolutionary techniques are also used to address energy resource optimization system for smart buildings [Markidis et al. 2015]. GA and Particle Swarm Optimization (PSO) were used to find the optimal trade-off between various resources and demands in the system.

Another related problem, also related to the RES uncertainties on EMS is the dynamic resource allocation, where an algorithm for multi-agent systems is proposed. In order to measure and deal with uncertainties imposed by the environment and the agents at run time, the proposed algorithm uses the social concept of trust [Anders et al. 2015]. Using uncertain information in the decision-making process, trust allows agents to quantify the information sources credibility. Their proposed algorithm allows the intermediaries to make informed decisions by taking uncertainties into account. However, for situations that agents do not provide an intermediary with all necessary information about their capabilities, they have described a technique that allows intermediaries to learn constraint models through observation with a specific implementation using Support Vector Data Description.

In other work, approaches using statistical modeling analysis are developed to derive a statistical distribution of energy usage, addressing the issue of quantifying uncertainties on the energy demand side [Yu et al. 2015]. On that work, they make use of several machine learning based approaches such as the Support Vector Machines (SVM) and Artificial Neural Networks (ANN) to carry out accurate forecasting on energy usage. Those techniques were used to effectively manage energy resources and usage in order to adapt to fluctuations, specially keeping the balancing between energy demand and supply. Another approach uses, the non-parametric Neural Network-based Prediction Intervals (PIs), implemented to forecast uncertainty quantification. A computational framework is proposed to build this important linkage through a proposed scenario generation method and the stochastic modeling. [Quan, Srinivasan e Khosravi 2015]. Whilst in another work, two prediction models are presented. One based on SVM and other based on Random Forrest, for energy consumption and weather forecast, comparing them afterwards. The another point is that they also use ANNs to forecast wind power generation. That gives us a broad overview of those methods [Landa-Torres et al. 2015].

The uncertainty handling on decision-making process is a soft spot on energy management systems, specially on those integrated with RES, as Smart Grids are. On [Dehghanian, Kazemi e Karami 2011], the authors tried to approach Remote Terminal Unities (RTU) incorporating expert knowledge on those. Those RTU are going to be considered as a crucial part of Smart Grid puzzle in power distribution systems, since they could be responsible for demand-side management. Besides, on that work, the authors propose a new qualitative-quantitative approach using Analytical Hierarchical Process (AHP). AHP was chosen for its applicability and robustness in solving the multi criteria decision making (MCDM) problems. AHP was used as basis and extended fusing Fuzzy sets to effectively deal with the existent uncertainties and imprecision. Thus proposing the FAHP algorithm, that is similar to the conventional AHP though, the verbal expressions are quantified in fuzzy mode and through fuzzy membership functions. They have used Triangular fuzzy membership function, which is a very common type of fuzzy membership function. That was chosen due to its simplicity and popularity, in here employed to deal with the existent uncertainties. That approach has exploited the robustness benefit of fuzzy to easily get through the existent uncertainties and imprecision in comparisons and judgment matrices.

Also using Fuzzy sets, focusing on electric load time series prediction, another work had shown a comparison between a Seasonal Auto-regressive Integrated Moving Average with Exogenous Variables Model (SARIMAX) and a Fuzzy Inference System [Pereira, Almeida e Velloso 2015]. Both models were used to predict the same time series of electric load from Bahia's State metropolitan area. In order to compare and evaluate the chosen methods, in both models different combinations of external variables were made. Exogenous variables listed for both models were: temperature, precipitation of rainfall and the number of customers. The chosen measures to evaluate the two algorithms was the Mean Average Percentage Error (MAPE) and Standard Deviation (SD). The proposed Fuzzy model is an Inference System Adaptive Neuro-Fuzzy (ANFIS). It had used the Takagi-Sugeno [Takagi e Sugeno 1993] method with constant output. The hybrid method in question is a combination of the method of least squares and the Back-Propagation gradient descent method. That work is the one that is most related to the one described in this work. Since they present a Fuzzy Inference System to energy forecast. Although they have found some issues on fuzzy rules generation, the proposed approach had led to solid results.

Given the fact that Smart Grid Controllers will constantly handle uncertainties of RES, predicting those uncertainties can yield positive results on decision-making problem. Focusing on uncertainties handling and prediction, other techniques were found on the SLR, such as Monte Carlo Simulation. However, simulations would just give insights, instead of real time information for decision-making. Nevertheless, despite Linear methods have given good results, the analysis of this SLR has shown that CI methods are being used on situations that robustness, accuracy and imprecision handling are main requirements for decision-making.

3.3.1 Final Considerations

In this chapter, we have presented the applications of some concepts defined in the Chapter 2. Those applications were grouped and analyzed in a Systematic Literature Review, where some related work could be found, specially to serve as guidance to our approach. The work found in this literature review have been used to identify methods that would handle uncertainties on decision making process for Smart Grid Controllers, therefore accomplishing its main goal. On the next chapter we will explain our approach based on these findings.

Appendix A

SUPPORT MATERIAL

Table A.1: SLR analysis of selected papers

Author	**Proposed Solution**	**Used Dataset**	**Which CI techniques are used in energy forecasting?**	**Which methods were used on decision making for EMaS control?**
[Dehghanian, Kazemi e Karami 2011]	This paper proposes a new qualitative-quantitative approach by taking Analytical Hierarchical Process(AHP) as the basis and extending it to overcome the existing inaccuracies associated with the experts knowledge and to effectively deal with the existent uncertainties and imprecision, using Fuzzy sets.	Iran' s power grid distribution network data	Fuzzy Analytical Hierarchical Process	Fuzzy Analytical Hierarchical Process
[Paparoditis e Sapatinas 2013]	They introduce a novel functional time series methodology for Short-Time Load Forecasting using, where the prediction is performed by means of a weighted average of past daily load segments, the shape of which is similar to the expected shape of the load segment to be predicted.	Electricity Authority of Cyprus Daily Load Data	N/A	N/A
[Hutterer, Vonolfen e Affenzeller 2013]	It proposes an approach for dynamic approximate optimization, where flexible control policies are learned offline that later provide (near-) optimal control actions at runtime.	Model data are taken from IEEE test case archive	Genetic Programing	N/A

Table A.1 continued from previous page

Author	Proposed Solution	Used Dataset	Which CI techniques are used in energy forecasting?	Which methods were used on decision making for EMS control?
[Tham e Luo 2013]	They have designed and prototyped a smart grid system architecture, that can operate either at the individual household level or at the community level comprising several households. The system make decisions on the quantity and timing of grid electricity to purchase, taking into account predictors of power demand and supply.	Not well specified Household	N/A	Linear Programing and Stochastic programing
[Soroudi e Ehsan 2013]	This paper presents the application of Information Gap Decision Theory (IGDT) to help the Distribution Network Operators (DNOs) in choosing the supplying resources for meeting the demand of their customers.	California ISO http://www.energyonline.com/data	N/A	Info-Gap Decision Theory

Table A.1 continued from previous page

Author	**Proposed Solution**	**Used Dataset**	**Which CI techniques are used in energy forecasting?**	**Which methods were used on decision making for EMS control?**
[Liu et al. 2014]	By the growing need of a automated self-healing grid, considering the complexity of the restoration emergency tasks moreover the time demanding efforts, the authors elucidate that smart grids may enhance the resilience and, ultimately, the self-healing capabilities by using advanced decision-support tools.	N/A	N/A	N/A
[Shann e Seuken 2014]	The design of a smart thermostat that automatically heats the home, optimally trading off the user's comfort and cost. This design is based on an algorithm that uses Gaussian Process and Markov Decision Process.	Swiss national meteorological service MeteoSwiss	Gaussian Process regressions and Markov Decision Process	Gaussian Process regressions and Markov Decision Process
[Liang e Chen 2014]	They proposed a novel algorithm to accelerate thecomputation of probabilistic Optimal Power Flow for large-scale smart grids through network reduction .	N/A	heuristic congestion forecast method along with K-means	ClusRed

Table A.1 continued from previous page

Author	**Proposed Solution**	**Used Dataset**	**Which CI techniques are used in energy forecasting?**	**Which methods were used on decision making for EMS control?**
[Puggelli, Sangiovanni-Vincentelli e Seshia 2014]	They proposed an algorithm for the synthesis of control strategies for MDPs, satisfying properties expressed in Probabilistic Computation Tree Logic (PCTL) and robust to uncertainties in the transition probabilities.	Data from the wind farm at Lake Benton, Minnesota, USA	N/A	Linear Programing and Mixed-integer Linear Programing
[Zhang et al. 2014]	This work proposes a power distribution system planning approach, based on a linear programming model.	N/A	N/A	Multi Criteria Decision Making using Linear Programing
[Anders et al. 2015]	This work presents a trust and cooperation-based algorithm that solves a dynamic resource allocation problem in open systems of systems.	N/A	Support Vector Data Description (SVDD)	Multi Agent Systems
[Pereira, Almeida e Velloso 2015]	It compares a Linear Model with a fuzzy model to predict time series of electrical load.	An Utility that operates in the State of Bahia, in BRazil (COELBA)	Fuzzy Inference System	N/A

Table A.1 continued from previous page

Author	**Proposed Solution**	**Used Dataset**	**Which CI techniques are used in energy forecasting?**	**Which methods were used on decision making for EMS control?**
[Ferruzzi et al. 2015]	Developing a bidding algorithm to solve the Economic Dispatch in a scheduling problem in a Micro Grid.	Italian electricity market	Genetic Algorithm	Analog Ensemble (AnEn) approach to quantify the uncertainty associated with the forecasted electricity production from RES.
[Yu et al. 2015]	Developing techniques to effectively manage energy resources and usage in order to adapt to fluctuations. Particularly, to balance energy demand and supply. They propose to develop effective techniques to accurately model and forecast the amount of energy generation and demand over time.	Real-world meter reading data set from Stanford University that consists of meter readings from houses over 200 days	SVM and ANN	N/A

Table A.1 continued from previous page

Author	Proposed Solution	Used Dataset	Which CI techniques are used in energy forecasting?	Which methods were used on decision making for EMS control?
[Landa-Torres et al. 2015]	Integrating renewable generation for smart grid control in a framework, incorporating computional intelligence techniques to predict energy generation and consumption along with weather forecast in order to infer their relation.	Historical data from Steinkjer/Rome meteriological Center	ANN, SVM and Random Forrest	N/A
[Markidis et al. 2015]	This paper proposes a benchmark of energy resource optimization system. It presents four algorithms comparing them to discover the one that performs beter to a given optimization function.	Data from a HVAC (heating, ventilation and air-conditioning system) system	MiniMax Algorithm, Genetic Algorithm (GA), Particle Swarm Optimization (PSO) and Quantum Particle Swarm Optimization (Q-PSO)	According to this work, the MinMax algorithm performs better for its analysis. However, the four algorithms can aid decision making on energy systems domain.
[Quan, Srinivasan e Khosravi 2015]	In this paper, the nonparametric neural network- based prediction intervals (PIs) are implemented for forecast uncertainty quantification. A computational framework is proposed to build this important linkage through a proposed scenario generation method and the stochastic modeling.	from an Albertawind farm, Canada, in 2012	Neural Network-based prediction interval	Genetic Algorithm, PSO based on an Lower Upper Bound Estimation and Monte Carlo Simulations for scenarios generation

Table A.1 continued from previous page

Author	**Proposed Solution**	**Used Dataset**	**Which CI techniques are used in energy forecasting?**	**Which methods were used on decision making for EMS control?**
[Athari e Wang 2016]	An uncertainty modeling for power grids to capture the dynamics of renewable energy generations and smart grid loads.	Electric Reliability Council of Texas (ERCOT)	N/A	Actually they don't cope decision making on their work. However they propose an uncertainty modeling with an hour ahead load forecasting using Traditonal Autoregressive Moving Average (ARMA) forecasting model.
[Connell, Soroudi e Keane 2016]	The work utilizes the Information Gap Decision Theory(IGDT) method in conjunction with the three-phase OOptimal Power Flow (TOPF) that method will be used as an operational tool to provide network operators with robust day ahead decisions for a particular LV network.	A LV network provided by the Irish DSO.	N/A	N/A
[Eremia, Liu e Edris 2016]	This work shows Computational Intelligence solutions that can be used on smart grid domain.	N/A	N/A	N/A

Table A.1 continued from previous page

Author	**Proposed Solution**	**Used Dataset**	**Which CI techniques are used in energy forecasting?**	**Which methods were used on decision making for EMS control?**
[Tanaka e Ohmori 2016]	A novel scenario generation method with K- means is proposed. This method generates electric load, wind, and PV-production scenarios representing uncertainty, which are used as input for stochastic programming, for decision-making on Distribution generation.	Power data of Tokyo Electric Power Company (TEPCO) are	K-means	stochastic linear programming
[Li, Wan e Xu 2016]	a novel robust trading model to derive the optimal Day-Ahead bidding strategy for a Wind Power Plants by minimizing its balancing cost. Robust optimization is applied to this problem to effectively take into account multiple uncertainties, where the conservativeness is adjustable.	Data from Nordic Market	N/A	Robust Optimization is applied to take in to account the uncertainties of Wind power generation.

Table A.1 continued from previous page

Author	**Proposed Solution**	**Used Dataset**	**Which CI techniques are used in energy forecasting?**	**Which methods were used on decision making for EMS control?**
[Dehghanpour et al. 2016]	The authors present a price-based DR procedure for Day-Ahead (DA) planning and decision-making in retail electrical energy markets using an agent-based framework. The framework uses an ANN parameterized via Bayesian Regularized Back Propagation (BRBP) in order to forecast loads to the agents decide a cost reduction problem.	Weather Underground	ANN parameterized via Bayesian Regularized Back Propagation (BRBP), Particle Swarm Optimization (PSO)	The consumers have the freedom to determine the trade-off between increasing cost reduction and reducing deviation from comfort zone, through private settings in their decision model. This problem is formulated as a Markov Decision Process (MDP) and solved via Q-learning.
[Farzin, Fotuhi-Firuzabad e Moeini-Aghtaie 2017]	A Multi-objective Optimization stochastic framework for optimal scheduling of Energy Storage Systems in a microgrid.	N/A	N/A	Stochastic programing and fuzzy decision making (FDM) method.