An Effective Classification Methodology Based-on the Practical Experience of Reviewing the Centralized Energy Management Systems for Microgrids

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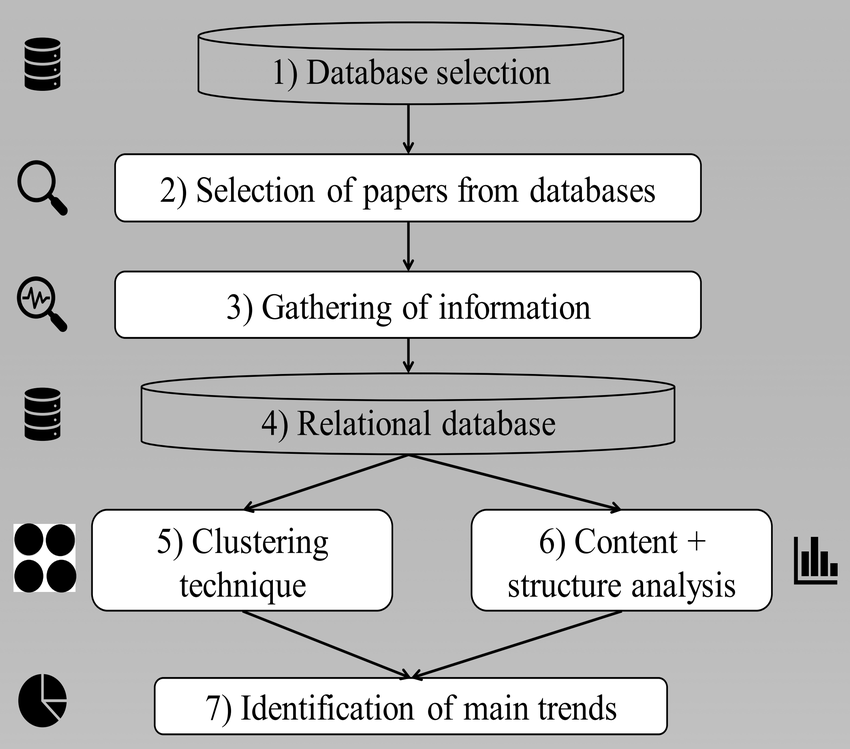
Introduction

This work presents a review to summarize the **state of the art** in the field of Energy Management Systems (**EMS**) for microgrids (**MGs**) with a focus on centralized control architectures. Then, based on the practical experience of the review development, an effective classification methodology that seeks to identify the main trends in centralized EMS for MGs is proposed. EMS attributes for several characteristics such as objective function, resolution techniques, operation model, integration of uncertainties, optimization horizon, and modelling detail levels are considered. With the use of a **Self-Organized Maps** (SOM) clustering tool, the following main research trends are identified: dealing with uncertainties, multi-objective strategy, traditional paradigm, and the P-Q challenge.

Proposed methodology



1) Obtaining information
- The database covers a comprehensive review of papers published in the most quoted journals in the field for the last 6 years.

2) Selection of papers from databases
- A group of papers covering the main topics of the research (EMS, microgrid, centralized control, etc.) is gathered by using IEEE Xplore, Google Scholar, ISI Web of Knowledge and Scopus search engines.

3) Gathering of information
- All the attributes selected from predefined classification levels are searched for and extracted from each paper.

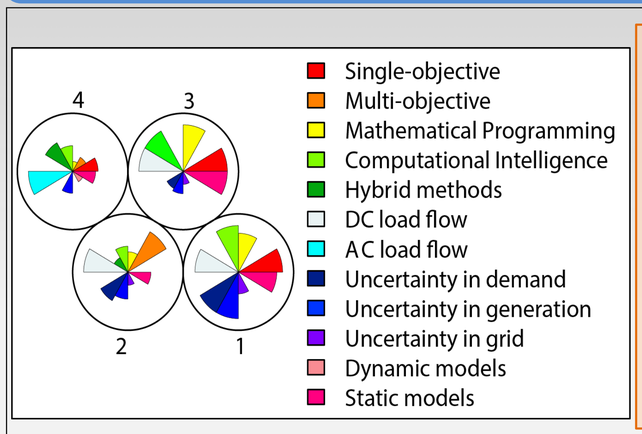
4) Relational database
- A relational database is created and populated based on the information from the attributes selected.

5) Clustering technique
- Various patterns are identified by means of a SOM (Self Organizing Map) clustering technique.

6) Content + structure analysis
- A statistical analysis is applied to the information of the database created. An analysis of the results is conducted.

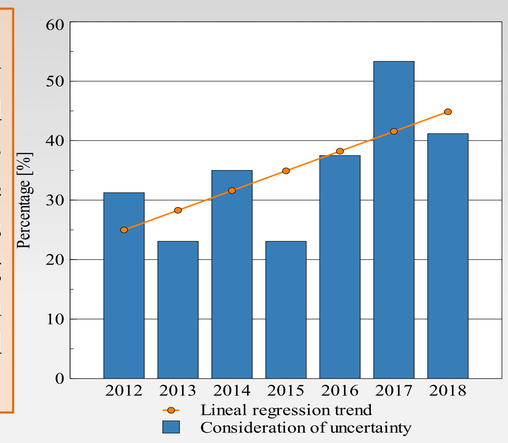
7) Identification of main trends
- Based on the results of steps (5) and (6) the Main Trends are identified and analyzed.

Summary Results



Qualitative results

The main trend is to use mainly computational intelligence-based methods to deal with a single-objective function. In addition the use DC load flow operation models together with static planning approaches and the consideration of uncertainties mainly in demand and generation are identified.



Example of numerical results

The consideration of uncertainty into the EMS mathematical problem increased in the recent years. This is due to the high penetration of RESs and their variability, which increases the challenges in the MG operation.

Cluster 1: Dealing with Uncertainties: comprises 33% of the references therefore becoming the main research trend. Its distinctive feature is the challenge of modeling the uncertainties present in various MG agents (DM, GE, GR) that will impact the performance of the EMS.

Cluster 2: Multi-Objective Strategy: contains approximately 29% of the references. This trend addresses a multi-objective approach. For this purpose, three resolution techniques are used for the resulting optimization problem, with a slight predominance of CI approaches.

Cluster 3: Traditional Paradigm: This third cluster contains approximately 21% of the references. By conceiving a traditional approach for EMS developments, the following options might be selected: SOBJ instead of MOBJ, a deterministic approach instead of focusing on uncertainty modeling, well proven MP approaches, a static representation of components (STM) instead of a DYM approach, and finally a focus on active power simulation (DC) vs an AC paradigm.

Cluster 4: The P-Q Challenge: This last cluster contains approximately 17% of the references. Proper management of reactive power requirements, voltage profile, ohmic losses minimization, and unsymmetrical operations are main issues in this trend.

Conclusions

The results demonstrate the existence of an active and dynamic research field that involves differentiated research communities. The classification methodology together results provide researchers and engineers with a guide to classify and to identify trends in centralized EMS. The numerical results show the evolution of each selected attribute in recent years. Finally, it may be reviewed whether the proposed methodology can become a generally valid classification methodology for other research fields.

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