PhD proposal in automatic control - 2021
Distributed optimization and its application to smart grids

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Keywords:
Automatic control, distributed optimization, control, multi-agent systems, smart grids

Subject:
This PhD thesis is concerned with the development of optimization methods when data is distributed through a communication network. This is for example the case of large networks (electricity distribution network, sensor networks, etc.) for which each node (agent) of the network has access only to its own information and the one of its neighboring agents and has only a local view of the network topology. From the information at his disposal, each agent makes a decision with respect to local constraints and communicates it to his neighbors.

Distributed approaches, whether in control or optimization, are attracting increasing interest as we look at the management and optimization of networked systems, and more particularly large networks. This is the case with new generation electricity distribution networks called smart grids.

Optimization using the multi-agent formalism is a recent contribution to optimization theory. This branch of optimization is currently in full development, stimulated by new applications related to networks. Classical optimization methods are based on the principle that all data is accessible at a single point. This principle is more difficult to apply to large networks where each agent has access only to local information and has also a local view of the network. The model is distributed and an optimization based on a distributed approach is better suited in this case because:

- of the large number of agents and the means of communication necessary to coordinate them,
- a centralized architecture is less robust to breakdowns and cyber-attacks,
- the scalability of the network is naturally considered.
The objectives of this PhD are as follows:

- to develop new distributed optimization methods and algorithms based on the formalism of multi-agent systems (MAS),
- to apply these theoretical results to electricity distribution networks. Distributed optimization approaches can potentially be used for a large number of network applications such as the problem of optimal power flow, frequency control, voltage control, management of power flows between micro grids...

The first objective of the PhD is to develop new distributed optimization algorithms using the formalism of multi-agent systems [3]. We will be particularly interested in the work developed in this context by Nedic and Ozdaglar at MIT [1,2] in the case where the problem is convex but for which the function is not always differentiable. The discontinuous gradient method developed in [7] could be used to improve Ozdaglar’s results. The recent results obtained on the consensus of SMA [4,5,6] will also be used. Other approaches such as proximal methods [8] could be tested during the PhD as an alternative to sub-gradient methods.

The second objective of the PhD is to apply the theoretical results obtained to smart grids in simulation on Matlab or on a dedicated simulator. The growing development of Distributed Energy Resources (RED) in electricity networks such as production sources (photovoltaic, wind turbines, thermal, etc.), storage units (chemical, thermal, hydraulic, etc.), controlled loads (vehicles electrical systems, air conditioning systems, intelligent applications, etc.) is leading to the change from a centralized network point of view to a decentralized network one. These resources, generally located on the consumer side, induce bidirectional power flows between the network and the consumer. The impact on the network of these growing resources raises some problems both in monitoring network stability and in optimization. In particular, the intermittent nature of renewable energy sources is a destabilizing factor for the grid. To fully benefit from the advantages of these resources without degrading the quality of the energy and the stability of the network, the idea is to set up a coordinated management of these resources aggregated in cluster, each cluster then appearing as an entity providing resources to the global network. This requires the development of distributed approaches able to responding to the following constraints while ensuring a viable business model [10, 11]:

- random and distributed renewable energy production associated with a demand that is difficult to predict, which complicates the adaptation of production to consumption, and leads to penalties for the manager,
- the heterogeneity of controlled loads and storage, which requires new models to take advantage of their flexibility,
- lack of measurements across the network,
- network scalability.

**Bibliography**


9. F. Guo, C. Wen, Y.D. Song, “Distributed control and optimization technologies in smartgrid systems”, Taylor & Francis, 2018


11. Tao Yang, Xinlei Yi, Junfeng Wu, Ye Yuan, Di Wu, Ziyang Meng, Yiguang Hong, Hong Wang, Zongli Lin, Karl H. Johansson, A survey of distributed optimization”, Annual Reviews In Control, pp. 278-305, 2019

**Desired profile:**
The candidate must have a master’s degree in mathematics or in automatic control. A good level in French or English is essential.

**Documents to be provided:**
- a resume and a cover letter,
- BS and MS transcripts,
- recommendation letters

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