Coordinating Generators in the Smart Grid

(Extended Abstract)

Sam Miller
Agents, Interaction and Complexity Group
School of Electronics and Computer Science
University of Southampton, UK
sjom106@ecs.soton.ac.uk

ABSTRACT

Due to highly constrained ageing infrastructure, current electricity networks will not be able to handle an increased amount of generation; particularly that from intermittent renewable resources deployed within distribution networks. In order to efficiently control this increased generation, decentralised autonomous control is the only viable solution; due to the computational complexities that arise for large networks. Thus, an agent managed smart grid will be essential for future electricity networks. Part of this system will be agent managed distribution networks that incorporate an increased amount of decentralised micro-generation from renewable resources. My PhD focuses on the algorithms and techniques needed for distribution network operators to use in order to coordinate generators within their networks efficiently.

Categories and Subject Descriptors

I.2.11 [**Artificial Intelligence**]: Distributed Artificial Intelligence—*intelligent agents, multiagent systems*

General Terms

Algorithms, Theory, Performance

Keywords

DCOP, electricity, max-sum, coordination, augmented Lagrangian

1. INTRODUCTION

Due to recent incentives for cleaner electricity generation [8], coupled with inefficient ageing infrastructure, the US Department of Energy [11] and the UK Department of Energy and Climate Change [10] suggest the modernisation of electricity networks that are able to incorporate additional generation, end consumers, smart meters, micro-storage devices and electrical vehicles in an intelligent and fashion. Due to the size and computation required to manage the smart grid efficiently, decentralised autonomous control of smaller distributed micro-grids is a very compelling solution [9]. The autonomous and intelligent nature of these distributed electricity micro-grids suggest that approaches from the literature of multi-agent systems [8, 14], and in particular, work on agent-based decentralised coordination algorithms [2, 6, 12], will be essential for delivering this vision.

One particular area of this smart grid is the challenges faced by distribution network operators (DNOs) in order to coordinate an increasing amount of renewable generators embedded in distribution networks (DNs) [4]. Firstly, DNs are already highly capacity constrained; adding additional generation that is not managed effectively may overload the networks [9]. Secondly, it is much harder to balance electricity demand with generation from intermittent renewable resources. If DNOs fail to balance supply and demand, the network can potentially become unstable which may result in brownouts, or cascading blackouts.

Thus, there is a clear incentive for DNOs to implement optimal dispatch[1] methods, within agent managed micro-grids, in order to address these issues. That is, how should the generators be coordinated, such that the cost of the network is minimised (i.e., in terms of carbon dioxide (CO_2) emissions or generator running expenditure), whilst satisfying the loads and network constraints. Coordinating generators with respect to network cost, is known as active network management (ANM), and has recently been addressed in the power systems community [3, 9].

2. RELATED RESEARCH

Within the ANM domain, a number of authors address the issues of coordinating generation from intermittent resources in the transmission network (where lines are less constrained than in DNs) [1, 2]. For example, Davidson et al. present an algorithm for changing the power outputs of the generators in the transmission network such that the cost of the network is minimised [2]. However, their technique involves a central authority calculating each generator's power output; who must have all the information about the entire network in order to calculate an optimal solution. As the size of the network grows, solving an optimisation problem in a centralised manner eventually becomes infeasible due to the exponential nature of the constraints [7].

In contrast, others have attempted to improve upon centralised approaches by decomposing the optimal dispatch problem and distributing the computation of its solution in order to improve its scalability [1, 6, 12]. For example, Baktirtzis et al. introduce a decentralised algorithm

[1]Optimal dispatch involves coordinating generators such that the loads and constraints of the networks are satisfied.

Appears in: *Proceedings of the 11th International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2012)*, Conitzer, Winikoff, Padgham, and van der Hoek (eds.), 4-8 June 2012, Valencia, Spain.

which uses augmented Lagrangian techniques using electricity network regions [1]. They decompose the optimal power flow equations into sub problems which are solved by each region iteratively using neighbouring variable values (i.e., the Lagrangian multipliers of the neighbouring regions constraints). However, their algorithm has only been tested on problems containing up to six regions. Moreover, within regions, the optimal generator outputs are calculated centrally, which for large regions may be infeasible due to the amount of centralised information required.

In the multi-agent systems literature, Kumar et al. introduce a message passing technique which extends distributed pseudotree optimisation procedure (DPOP) to solve the related area of research for reconfiguring feeder trees within a DN [6]. While this approach is decentralised, and was shown to work on realistic sized networks, it does not address the problems highlighted above of incorporating an increasing amount of distributed generators (DGs) in DNs, and the need to coordinate their output.

Vytelingum et al. tackle the optimal dispatch problem by managing the trading of electricity between nodes on a network [12]. However, their technique has only been tested on problems containing up to 16 nodes. Thus, again it is unclear whether this approach could be applied to a larger network. Moreover, their technique is partially centralised; since each agent needs to know the entire network topology. In a large network, maintaining this system-wide knowledge is problematic, especially when faced with renewable generators whose output is continuously changing.

Against this background, there is a clear need to address the challenge of coordinating large numbers of renewable generators, embedded in DNs. Appropriate solutions should distribute the computation required (due to network size), efficiently calculate a solution, and ensure that the solution adheres to the network constraints and minimises costs of running the network.

3. CURRENT THESIS RESEARCH

To date we have addressed the issues raised in the previous section, particularly the challenge of coordinating large numbers of renewable generators, embedded in DNs, by decomposing the optimal dispatch problem into a decentralised agent-based coordination problem; represented as a distributed constraint optimisation problem (DCOP). This work has been accepted at AAMAS 2012 [7]. In more detail, each node in the network is represented by an agent which undertakes some of the computation required to solve the optimal dispatch problem; such that demands within the network are satisfied and CO_2 emissions of the entire network are minimised.

In particular, we solve the optimal dispatch problem on the most common DN types (i.e., radial networks), which tend to have a high number of branches and sources [13]; for which centralised solutions scale poorly. Crucially, our algorithm handles the complexities of balancing flows within the network, *without needing central verification* of a particular solution.

However, another common form of DN is the ring main, which consists of many radial networks connected in a loop. Applying the same techniques used in [7] to a ring main network is not straight forward since when the network contains a loop, flow in one distribution cable is affected by multiple parts of the network simultaneously; if one of the generators changes its power output on the loop, the impedance of each distribution cable affects the amount of power that flows along it.

Therefore, a different technique is needed which explicitly takes into account the coupled nature of a ring main network. As a starting point, we have researched the techniques in [5] which use augmented Lagrangians. However, instead of using regions, we consider individual nodes within a network. The techniques in [7] will be used to propagate the costs of generating certain amounts of power in the radial parts of the ring main network. Then, each node in the ring of the ring main will use augmented Lagrangians to iteratively calculate their optimum power outputs, based on the constraints of the network and the values calculated in their respective tree networks.

4. CONCLUSION

My thesis research is directly addressing the optimal dispatch challenges faced by DNOs. Namely how an increasing amount of cleaner DGs can be added to already highly constrained DNs, and coordinated in an efficient fashion using optimal dispatch. In [7] we provide a DCOP formulation of the optimal dispatch problem and provide a novel algorithm for coordinating generators in a radial DN. Current research incorporates other common DNs, particularly ring main networks. For this research, augmented Lagrangians is the most prominent starting point.

5. REFERENCES

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