Examination Report for the thesis "Investigation of Market Mechanisms for Distribution Level Energy Management" by Mark A. Burgess

This PhD thesis investigates market mechanisms for energy management at the distribution level. The focus is on electricity grid. The candidate has been working toward the PhD at the ANU College of Engineering and Computer Science.

The main question the thesis aims to answer is "what market structures should be implemented?" within the context of electricity distribution and modern Distributed Energy Resources. The thesis uses game theory and mechanism design as main methods to answer this question, in addition to presenting some results on sampling methods. The main contributions of the thesis are 1) introduction of GNK (Generalized Neyman and Kohlberg) value as an axiomatic extension of classical Nash bargaining, 2) application of GNK to electricity distribution models, 3) new concentration inequalities in the context of stratified sampling.

The novel contributions of the thesis were published in two conference articles in prominent computer science conferences. Overall, the research questions the thesis investigated, and contributions are worthwhile and interesting. However, the thesis in its current form has room for improvement and some issues should be addressed before publication.

Specific Comments

Chapter 1

The chapter gives a nice overview of the research questions and contributions. However, it assumes that the reader has familiarity with the ongoing transformation of electricity systems, especially in Australia. An important issue here is the lack of background information on technical aspects of the application domain, namely the electricity generation and distribution systems.

Chapter 2

Although this chapter touches important and deep topics, in my opinion it creates a distraction in a technical PhD thesis at the College of Engineering and Computer Science. The contributions of the thesis are not dependent on the philosophical speculations. They stand on their own as axiomatic and computational results. Therefore, I recommend moving this chapter to the end of the thesis, where it can provide a valuable philosophical context and discussion.

Chapter 3

This chapter presents a very nice overview of existing methods from mechanism design literature. Therefore, it serves as a good background chapter in that specific aspect. However, it also highlights the two very important issues with the thesis: 1) there is no discussion on

how the technical aspects of the problem, i.e., electricity systems constraint or affect such mechanisms. In relation to this, there is no proper background information provided about technical underpinnings of the systems the thesis claiming to investigate, 2) the thesis does not contain a proper literature review of the many works that apply market-based and game-theoretic methods to the exact same problems addressed in the thesis. This naturally makes it impossible to put its contributions into proper context and appreciate them fully.

Chapter 4

This is the main contribution chapter of the thesis where a novel GNK value is introduced and applied to a basic electricity distribution model. The results presented are interesting and promising. It is one of the best chapters in the thesis.

Chapter 5

This chapter suddenly jumps to the topic of stratified sampling, without properly clarifying the context other than referring to a subsection in Chapter 4. The literature review is well done and relevant background information on sampling is provided. This chapter contains very interesting results on sampling and good theoretical contributions. However, it feels totally disconnected from the rest of the thesis. The connection between the results in Chapter 5 and the problem solved in Chapter 4 is easy to miss and is not highlighted enough.

Chapter 6

The discussion in this chapter is too short. The opportunity should be used to establish the nice connections between axiomatic contribution of GNK value, theoretical results on sampling that contribute to computation of GNK, and their applications to distribution grids. I believe this has priority over philosophical discussions for clarifying the valuable contributions of this thesis.

Recommended Changes

1) The thesis should contain substantial new material reviewing relevant literature, focusing on the fields of energy economics, especially works that combine technical/computational aspects of the problem with game-theoretic methods. This is necessary to put the contributions of the thesis into context.
   The literature mentioned in the thesis focuses too much on fundamentals of mechanism design methods from mid-20th century and almost totally disregards vast literature on energy and electricity applications. A specific starting point, for example, could be works by Ben Hobbs, https://hobbsgroup.johnshopkins.edu/ and references therein. VCG and variants have been applied to electricity markets and energy management by tens of papers, see e.g. online resources such as Google Scholar with keywords ‘vcg electricity markets’
2) The thesis should provide more background on electricity distribution systems it targets and emphasise the effects of these technical systems on the mechanism design problems.

3) The connection between Chapters 4 and 5 should be strengthened, and how the results of Chapter 5 play an important role in the overall theme of the thesis should be clarified.
4) An extended discussion should be included at the end of the thesis, providing the connections between the individual contributions of the thesis, the application domain, and their value within the context of the broader literature.