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Nanogrid Yoke

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Declaration

I hereby declare that this project is entirely my own work and that it has not been submitted as an exercise for a degree at this or any other university.

Brian McNestry, May 5 2017

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Abstract

This is the abstract

Acknowledgements

Acknowledge the various people here

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Chapter 1

Decentralised Grid

At present in Ireland and in many other countries, the national electric grid infrastructure is controlled by a central body, namely the ESB. While there are several electricity providers in Ireland, such as Bord Gáis Energy, SSE Airtricity and Energy Ireland, each of them use the same distribution network as one another. Essentially the power is provided from each of the different providers and then routed into the same centralised hub belonging to the ESB. From there, each consumer (a household) receives the energy that they pay for accordingly at a fixed rate through that same infrastructure belonging to the ESB. This is much the same system as any other country, where there is a centralised grid.

This system has been in place for decades and lends itself very well to the situation where large companies can provide a steady supply of energy by way of electricity plants that use both renewable and non-renewable energy sources. Non-renewable energy sources, also known as fossil fuels, include resources such as coal, gas and oil. While these are finite resources, at present they can be burned at a steady rate in order to meet the demands of customers. Electricity from renewable sources can also be produced at a fairly steady rate by placing large farms in areas that are particularly well suited to the type of renewable energy being produced. For example, large wind farms are set up in windy regions far removed from residential or urban areas and solar panels can be placed in regions that typically enjoy clearer skies than other areas.

However in the future, perhaps the very near future, with the ongoing depletion of non-renewable resources, more and more people will turn to deploying solar panels and local wind farms in their locale, regardless of whether or not they are living in a particularly sunny or windy area. At the moment there are a few houses out there that use a solar panel to heat their water or other smaller tasks but soon more and more people will become more and more dependent on what they can produce either within their own home, or in a more collective sense in their own neighbourhood to power their houses.

The issue that then arises in these areas that aren't as sunny or windy is that supply of electricity is no longer steady. The current system could not be maintained as the energy produced on a local level would be small enough that it would not be worth it to pass this energy upstream to the central grid. The energy would instead be used at a local level to try to cover the demand for electricity of the house or business with which that particular device is associated.

The model of infrastructure that would then be required is that of a decentralised grid. This model would need a massive infrastructure overhaul in order to implement so it would not exist in the world until it is needed and accepted by the major companies who would then go about implementing it. In this case necessity would be the mother of invention, at least on a practical level. The rough idea of a distributed grid is described in figure 1.1. Throughout the rest of this report distributed grid and decentralised grid are used interchangeably.

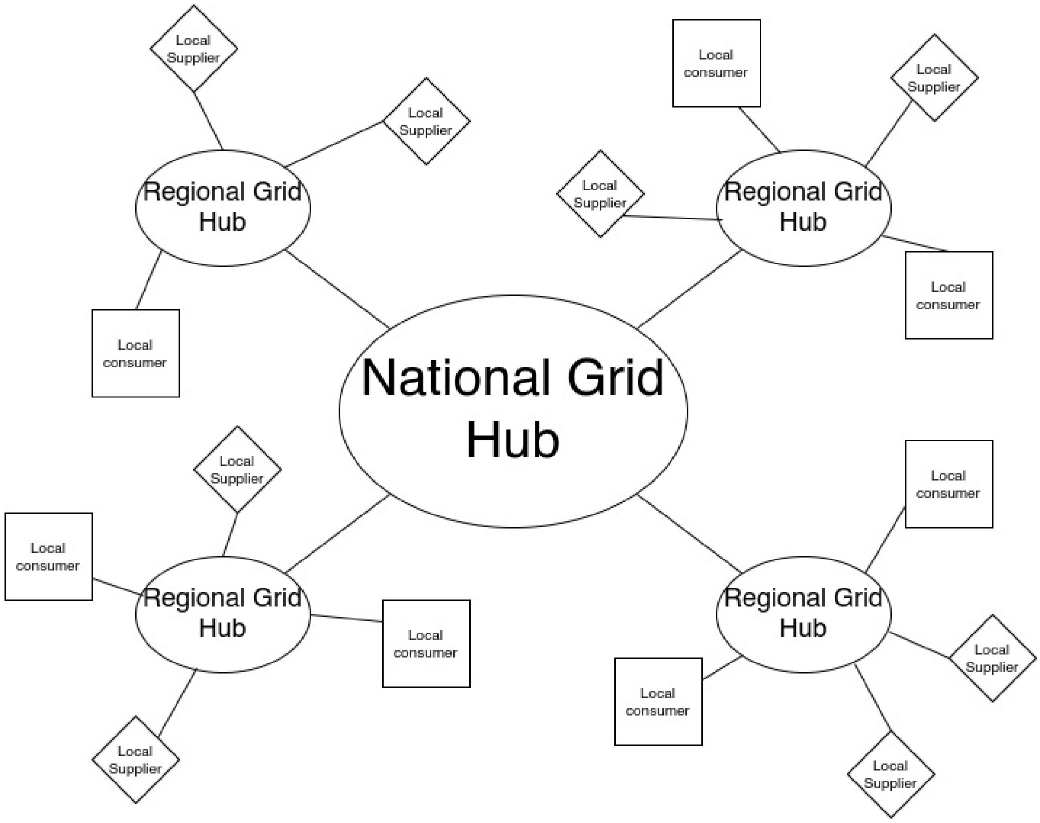

Figure 1.1: Each local consumer and supplier is attached to a regional grid hub which manages the allocation of electricity between suppliers and consumers. This is just a simple overview of the idea but conceivably a consumer or a supplier could be connected to two or more different regional grid hubs.

Chapter 2

Smart Grid

Due to advancements in networking technologies as well as in the field of sophisticated decision making technologies, the idea of a smart grid has become increasingly popular. The idea of the smart grid is that actors within a grid, be they individual consumers or suppliers, or groups thereof, can be fitted with small computers that perceive changes in the grid and then these actors can then react accordingly. Several different types of management systems have been constructed in order to successfully, fairly and efficiently allocate resources for each of these different types of actors. The two primary types of management systems that were examined as part of this final year project were Auctions and Game Theory which will both be discussed in detail later on.

The smart grid is not only used in this regard but in fact has many other potential applications, some of which have been implemented already in several cities and regions throughout the world. Other applications of the technology include energy consumption or production prediction, scheduling the use of consumers in order to reduce costs or operation and smart reaction and response to disruptions or blackout within the grid to reduce the damage that occurs as a result.

In this project it is assumed that the consumers within the system are outfitted with some kind of prediction technology. An example of such a system has been proposed by Garcia et al [1] where a device tries to time its own operation within a certain time-frame in accordance with when the price of energy is cheapest. It also tries to predict how much energy it will consume based off its own knowledge of previous experiences in buying power at that particular time of day, allowing the system to learn over time and make smarter decisions as time goes on.

2.1 Microgrids and Nanogrids

At present smart grids have generally been implemented on the level of microgrids. Microgrids are generally thought of in terms of having a consumer be a single house, or perhaps a group of houses, and a supplier being a small wind farm or solar farm, or perhaps a group of these together. In the case of a microgrid, actors within the system are defined in similar to the units involved in a centralised grid system meaning that the transition from a centralised grid to the microgrid scheme was a relatively easy one.

An example of such a real world implementation is that of the system in place in Japan. This system was mostly implemented following the disaster of Fukushima, where it became clear that a reliance on a single power source and a centralised power distribution network left the country vulnerable following the disaster [2]. Several regions were cut off from power as a result of the disaster which hampered the relief efforts as well as making the lives of ordinary Japanese citizens more difficult. Had a microgrid system been in place then not so many hospitals and homes would have been left without power following the disaster. The company ENEL has also introduced a smart grid system in the region of Apulia in southern Italy [3].

The nanogrid system is very similar to that of the microgrid system conceptually but is concerned with a much smaller scale. A nanogrid is one that operates within the confines of a single building, generally where each consumer is a single appliance such as a washing machine or an electronic vehicles (EV). Suppliers would also be very small scale perhaps a set of solar panels or a small wind turbine. A nanogrid system could also be adapted to aggregate a number of devices to act as one as a single actor within the nanogrid system, for example all the lights on one floor of a house could act as a single consumer and draw on a shared reserve of power.

Another extension of the nanogrid system, which will be discussed in further detail in the conclusion section of this paper, would be to incorporate a nanogrid as a sub-node of a microgrid. This would create a hierarchy of distributed grids. This tree could also be adapted into a graph where a parent node in the tree could have multiple children and a child could have multiple parents. This will be discussed more in the conclusion.

Chapter 3

REFIT Scheme

Chapter 4

Auctions

Chapter 5

Game Theory

5.1 Overview

The field of game theory has been one that has many different facets and versions depending on the type of situation required. In this section of the report the nomenclature and jargon of game theory will be discussed, as will a short explanation about the decision of selection of the type of game implemented as part of this final year project. First the two primary types of interactions between players in a game will be discussed and after that the two primary types of playing styles will be discussed. However first of all there are certain traits that are universal for any type of game that must first be explained in order to grasp the concept of game theory enough to understand some of the implementation decisions later in this report as well as to grasp the general concept of game theory itself.

In game theory, players within a game compete for a finite resource with the objective of maximising their own utility within the scope of that game. Each player within the game has an associated utility function that is generally the same for all players within that game. The utility function generally results in some scalar value that is trying to reach some max value, whether on an individual or collective level. There is also generally some kind of manager node that helps to conduct the game between all of the players involved. Within any particular game, the players are all trying to maximise their own utility, however in different types of games they may also be conscious of the utilities of all the other players involved and try to react accordingly, whether to further their own goal or to further the goals of the collective group.

A well defined game also has some from of state of equilibrium. This state of equilibrium is when the sum of utilities of all the players within the game reaches a maximum. The central managing node, if there is one, generally decides whether or not this state has been reached. This state is the success state of the game. In a well-designed game the utility function must be designed such that the state of equilibrium not only can be reached but also that reaching that state is appealing to all players within the game.

5.2 Non-Cooperative Game Theory

Non-Cooperative games are the simplest types of games to both understand and design. As previously stated, each player is trying to maximise its own utility but the core component of a non-cooperative game is that all of the players are operating purely independently. Each player within the game knows the best strategy to take in order to maximise its own utility. Because each player in a game has the same moves open for them to take and therefore the same strategy that each other player will take to maximise their own respective utilities.

This is where the concept of Nash Equilibrium comes into play. Nash Equilibrium is the state in which there is the least disparity between the best player and the worst player, that is that each player performs the best that it can with the knowledge that all other players are similarly going to try to maximise their own utilities. With this knowledge, each player is then able to pick the strategy that maximises its own utility, taking into consideration that all other players are trying to do the exact same thing and therefore it picks an appropriate strategy. In a well designed game, there should also be no incentive for a player to change their strategy to try to undercut other players. If made correctly, such an action would have an adverse effect on the player in the game. In this case all other players would then be aware that this players strategy had changed and would then react accordingly in order to maximise their own utility and decrease that player's utility.

5.3 Cooperative Game Theory

5.4 Cournot and Stackelberg Games

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