# Modelling of a Hybrid Energy System Using Automata

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These days, we are observing transformation in electricity industry at a pace and scale that we have never seen before. Unidirectional flow, for which our grid was made is no longer an option. Centralized generation is now being taken over by distributed generation which has changed the unidirectional flow of energy to multidirectional flow in our grid. Although the decentralized generation allows the integration of more Renewable energy sources (RES) which seems to be the solution for environmental and economic challenges we face today. However, at the same time increased penetration of DERs into the grid is raising many concerns about grid safety. These concerns can be dealt with if we decide to redesign the whole grid but this would require huge sum of investment which makes it almost impossible to do. Increase in population, suburbanization and industrial development are the reasons for increased energy demand these days. Large centralized power generation requires building huge operational infrastructures and utilizes conventional energy resources like coal, gas and nuclear reactors. Although the efficiency of these systems is greater but the raw material required for these power plants is continuously being depleted from the earth's core. At the same time the by-products of such systems are causing more harm to the earth environment then good. For these reasons, the trend is now being shifted towards local or decentralised generation.

The challenges we face to integrate renewable resources into the grid are mainly due to their variable nature. They are highly dependent on environmental conditions for their generation capacity for example, solar generators would be rendered useless in the absence of solar radiation or wind generators will not generate any power if there is no wind to rotate the turbine. To tackle these issues, hybrid energy systems is more reliable, giving us more control over the energy production. Hybrid energy systems are usually comprised of one or more type of distributed generators, which may or may not include RES, backed by energy storage systems. So when one or more generators fail to produce required electricity, energy storage takes over for them to maintain the supply.

The purpose of this research is to model a hybrid energy system for a university owned farm, called Cockle Park Farm. The farm is owned by Newcastle University for multi-disciplinary research to be carried out in order to find the solutions for mainly energy and agricultural challenges faced in rural areas. It's a 'living lab', combining research with economic and environmental benefits for the farm by working with industry, NGOs and the farming community. Recently, the electric supply system of the farm is being upgraded and designed for the new facilities. This provides us with an opportunity to explore the possibilities other than relying just on the grid supply and to design a hybrid energy system using the resources available at the farm for more efficient and economic supply system. These resources include a biogas run CHP unit, Energy Storage, some rooftop solar panels and the grid supply. The farm still has more room to upgrade in future and accommodate more generators like wind farm or more solar generators. At the moment, it runs on a weak supply of single phase which is most common in rural areas. But recently, a single to three phase converter is installed at the farm to run an anaerobic digester. The biogas produced by anaerobic digester has relatively low concentration of

methane (50-65%) which makes it hard to sell for revenue. However, this biogas can be used by the CHP to produce thermal and electrical energy. The target is to minimise the cost of supply by generating most of the energy within the farm and trade surplus energy with the grid to maximize the farm's profit.

The purpose of this research is to design a generic model of hybrid energy system for cockle park farm and study its behaviour. Discrete control can be applied to operate the analogue plants or subsystems involved in this energy system. For that purpose, we are proposing the use of hybrid automata to model the system. Hybrid Automata has been used to model complex hybrid systems, for example in [_], use of HA to model linear hybrid systems is proposed. [_] shows how reachability analysis techniques in automata can be used to simplify the complicated trajectories in hybrid systems.

Hybrid power systems involves several units of variable capacity. In order to generate a controlled output from each asset, require complicated control strategies that are difficult to be modelled or represented using traditional methods like flow charts. Complexity of the system grows with its scale as more DER and loads are added to system. In our work, we will show how discrete control designed using HA can control the continuous generation of the system. Key to this overall operation will be the "reachability analysis" of HA which can allow us to define and reach specific desired operational states. The focus of this paper is on demonstrating how HA can be used to model and control a hybrid energy system of a farm but this research will also show if we can use the same tools to model even more complex systems.