Title: **Feasibility of applying Blockchain and smart contracts technology to distribution grid management in the GB power system**

Synopsis: The aim of the project is to validate the feasibility of applying Blockchain and smart contracts technology to the distribution grid management in the GB power system. This is measured by the extent to which the distributed ledger is able to improve the balancing serviced in DSO enabled distribution networks.

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Executive Summary

The aim of the project is to validate the feasibility of applying Blockchain and smart contracts technology to the distribution grid management in the GB power system. This is measured by the extent to which the distributed ledger is able to improve the balancing serviced in Distribution System Operator (DSO) enabled distribution networks.

- A proof of concept smart contract will be implemented and demonstrated using a simulated Blockchain. This will be linked with desktop-based power flow simulations of a distribution network with many distributed energy resources (DERs) and energy consumers.
- The interaction between different players enabled by smart contracts and their impact on the distribution network system balance will be compared to that of the network with alternative methods such as a centralised control with virtual power plants.
- The performance will be analysed to validate the feasibility of applying Blockchain and smart contracts technology to distribution system management.

A summary of activities are presented below.

1) **Hardware implementation: A private Blockchain was created, and integrated with power flow simulations and control of distribution network.**

   A private Blockchain consisting of three players was built using the software platform Ethereum. Three laptops were connected together in a local area network (LAN) using Ethernet cables. Each laptop represents a customer who will carry out energy trading in a distribution network. The Blockchain is running among these laptops, and the energy trading in each single customer is updated and recorded in the private Blockchain.

   Further developments will include a link between the desktop computers which run power flow simulations and the Blockchain to improve the design of the smart contracts. Interface of the link between the power flow simulations and the Blockchain was investigated. The results of the energy trading, running through the private Blockchain, were taken as the inputs of the power flow simulations. The power flow simulations will help to improve the smart contract design, where the flexible demand and generation are able to be rescheduled by certain pre-defined rules.

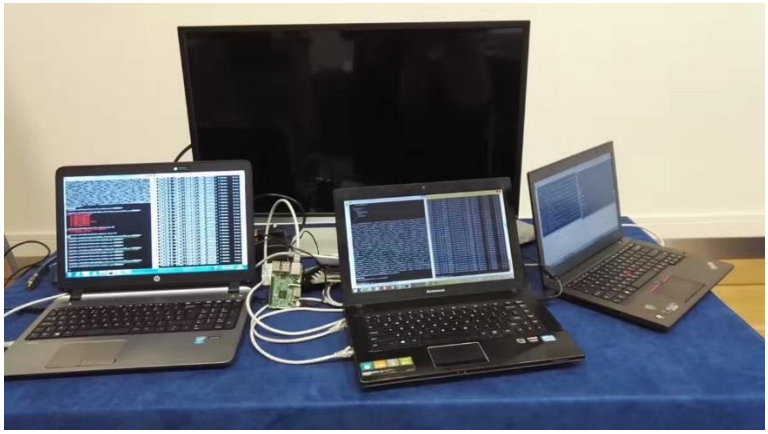

Fig. 1. A private Ethereum Blockchain running in a local network area (LNA) used for distributed energy trading

2) **Computer based study/simulations: The interactions (control set-points) between different DSOs were analysed where Blockchain and smart contract would be used. The interactions between multiple prosumers (i.e. players in the game) is under investigated using a game theoretic approach.**

The control set-point of active power flowing through networks when these network are managed by different DSOs were analysed, and smart contract containing different rules to determine the set-points were developed. The use of smart contract addresses the trust issues when involving different actors in the future energy systems.

The interactions between prosumers in distribution networks were studied using a game theoretic approach. This helps the prosumers to make control actions anticipating the control activities of other prosumers.

3) **Project Impact: The study on Blockchain technology and smart contracts brought a new project funded by industry (with ~£150k to Cardiff University) and papers submitted to Nature Energy and other peer reviewed journal papers with high impact factor.**

The study on Blockchain and smart control has brought the attention/interests of three Distribution Network Operators (DNOs), and they are SP Energy Network, Scottish and Southern Energy (SSE), and UK Power Networks (UKPN). The three DNOs jointly fund Cardiff University for a project, named Distributed ledger technology - Enabled Distributed System Operation (DeDSO). This project brought ~£150k to Cardiff University.

The research work has been properly conducted and summarized. 3 papers in this areas have been submitted in peer reviewed journals with high impact factor, including one paper submitted to Nature Energy. The acknowledgement will include the project title funded by ENCORE.

In summary, building the environment for testing of proof of concept of smart contracts in a private blockchain is completed. There are some further development on integrating the Blockchain with power flow simulations and control of distribution network ongoing. Computer based simulations to investigate the interactions between different players enabled by smart contracts are carried out. Here, the game theoretic approach is also used. Most importantly, the study on Blockchain and smart contract brought a new project funded by power industry (with ~£150k to Cardiff University), and a few papers are submitted to journal with high impact factor including Nature Energy.