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Programme Area: Light Duty Vehicles

Project: Electricity Distribution and Intelligent Infrastructure

Title: Executive Summary

Abstract:

This project was undertaken and delivered prior to 2012, the results of this project were correct at the time of publication and may contain, or be based on, information or assumptions which have subsequently changed. The Electricity Distribution and Intelligent Infrastructure project (TR1002) is comprised of six Work Packages. This Executive Summary covers Work Package 2.1. The purpose of this Work Package was to determine what barriers may exist within the UK electricity distribution system, develop potential mitigation strategies and create a macro-level model to enable city-level planning of recharging infrastructure deployment.

Context:

This project looked at the potential impact of electric vehicles on the UK electricity distribution grid.

ETI Executive Summary

Programme: Transport – Plug-in Vehicle Economics and Infrastructure

Project: Electricity Distribution and Intelligent Infrastructure (TR1002)

Work Package(s): 2.1

Final Deliverable(s): SP2/EDFEN/04 and SP2/IMP/18

Version: *1.0*

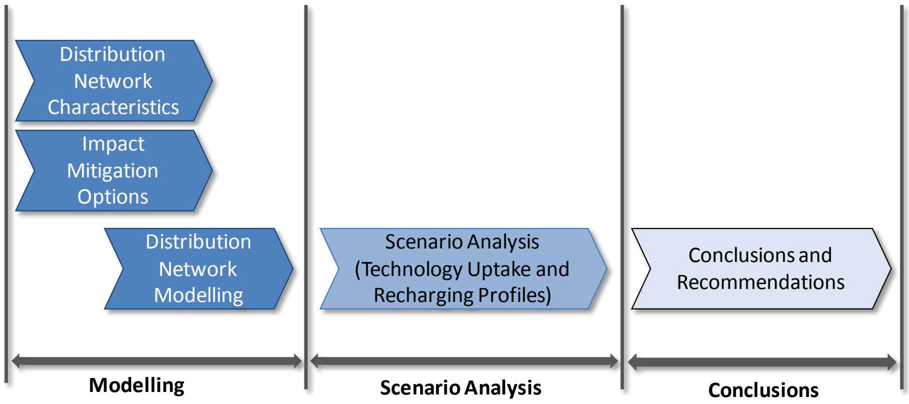
Introduction

The Electricity Distribution and Intelligent Infrastructure project (TR1002) is comprised of six Work Packages. This Executive Summary covers Work Package 2.1.

2.1	Network Analysis
2.2	Recharging Network Requirements
2.3	Recharging Infrastructure Cost Driver Analysis
2.4	Intelligent Architecture
2.5	Recharging Infrastructure Implementation
2.6	Consumer Testing Framework

The purpose of this Work Package was to determine what barriers may exist within the UK electricity distribution system, develop potential mitigation strategies and create a macro-level model to enable city-level planning of recharging infrastructure deployment.

A high-level overview of the analysis is shown below.



Modelling

Eight 'representative' networks were identified, and are briefly summarised below. The representative networks were selected to reflect specific consumer mixes and layouts associated with different network areas which, in combination, can accurately reflect the aggregate distribution network.

Key design parameters incorporated include the geographic area, consumer density, the Low Voltage (LV) and High Voltage (HV) network density (in terms of cable lengths per km^2) and distribution transformer density.

Five categories of consumer were used to define the consumer mix for a particular representative network: domestic-unrestricted, domestic economy-7, small non-domestic, large non-domestic and HV large demand.

Representative Network Name	Key Characteristics
Rural 1	• Driven largely by customers on unrestricted domestic tariffs and large industrial demand. • Small morning peak.
Rural 2	• Driven by domestic consumers on economy-7 tariff. • Night time peak demand.
Semi Rural 1	• Mix of domestic consumers and small non-domestic loads. • Relatively flat demand profile.
Semi Rural 2	• Influenced by large non-domestic consumers. • Peak demand during the day, but high night-time load due to economy-7 consumers.
Sub-Urban 1	• Dominated by domestic-unrestricted consumers • Peak demand during the day
Sub-Urban 2	• Driven by non-domestic consumers • Higher peak demand during the day
Urban 1	• Dominated by domestic and small non-domestic load. • Moderate day-time peak.
Urban 2	• Influenced by fewer large non-domestic customers. • Moderate day-time peak.

A range of impact mitigation options were identified and evaluated. In summary:

- **Network reinforcement** involves increasing equipment rating to overcome thermal overloads and to mitigate voltage violations. Inserting distribution substations to reduce LV circuit length and to eliminate voltage and thermal problems was also considered. Inserting new distribution substations in existing networks might only be applicable in some rural and semi-rural areas. This is mostly due to the prohibitive cost of land in urban and semi-urban areas and the potentially expensive extensions of HV networks.

- **Voltage control** can be very beneficial as a significant number of network constraint violations are related to voltage. This can be achieved by applying voltage regulators in LV and HV feeders with voltage constraints.

- **Dynamic thermal rating** is a technique of continuously monitoring and adjusting circuits' ratings. This option is not considered to have a significant impact on the majority of LV and HV networks.

- **Dynamic feeders' reconfiguration** is a technique of continuously monitoring circuit power flows and voltage profiles and switching load from one feeder to another. This option is considered for HV networks with normally open points. It is envisaged that this would require the presence of distribution network intelligence and remote control to provide active control of load flows and to manage local network constraints.

- **Storage technology**, applied to alleviate network constraints.

- **Phase load balancing** is aimed at balancing network loading across the three phases by suitably reconnecting consumers to different phases. This would be particularly material in cases of significant load imbalance between phases (it is unclear how material this problem may be).

- **Smart charging** will provide a major opportunity for mitigating network reinforcement due to increases in vehicle uptake.

- **Smart-meter based energy tariff** is a technique based on commercial arrangement with the aim to encourage price sensitive consumers to modify their energy consumption patterns.

- **Smart appliances** are controlled through time shifting in order to reduce network peak demand.

- **Smart heat pumps with heat storage** will increase loading on the network (if the heat sector is incorporated into the electricity system). Coordinating heat pump operation together with recharging of vehicles may reduce requirements for network reinforcement.

- **Reduced consumer energy needs** from new energy efficiency measures such as micro generation, better insulation, solar heating, use of more efficient appliances and lighting, etc. This may also change the energy demand pattern and peak demand and hence release some network capacity.

- **Distributed generation** may release network capacity but also cause network reinforcement.

Using the data on representative networks and the evaluation of the potential mitigation options, a macro-level mode was developed. The diagram below provides a high-level summary of the model development.

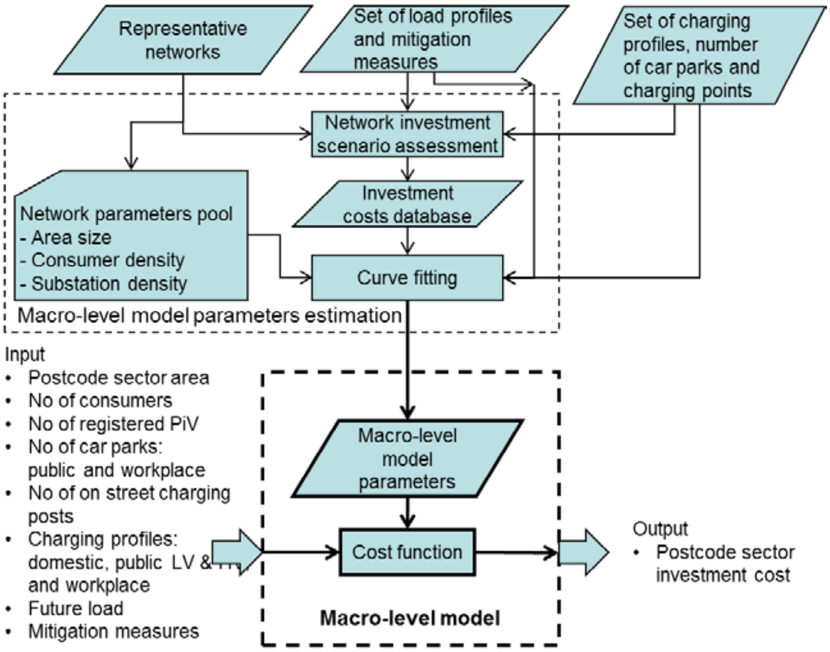
The input parameters of the macro-level model are:

- **Postcode sector area** specifies the area size in km^2.

- **Number of consumers** specifies the number of LV connected consumers in a postcode sector.

- **Charging profiles** are aggregate winter working day charging profiles for domestic, workplace and public for both on street and in car park charging posts.
- **Number of registered plug-in vehicles** practically specifies the number of domestic charging points in a given postcode sector.
- **Number of car parks** specifies both the number of workplaces and the number of public car parks offering vehicle recharging facilities in a given postcode sector.
- **Number of charging points** specifies the number of on-street recharging points in a given postcode sector.
- **Future loads** includes the number of heat pumps and micro-combined-heat-and-power units, the percentage of peak demand growth and peak demand reduction, for example, due to application of energy efficiency measures.
- **Mitigation measures** specify the possible actions to mitigate investment in the distribution network.

The output is the distribution network investment cost for a given postcode sector.



Scenario Analysis

A range of scenarios to 2050 were analysed, including three vehicle uptake projections and three discrete recharging regimes (and combinations thereof). In addition, other important factors were tested, including (amongst others):

- Variable distribution/concentration of vehicle uptake in 'hot-spot' locations;
- Uptake of other technologies, such as heat pumps;
- Deployment of other mitigation measures, such as Economy7 heating control; and
- Peak demand growth and efficiency improvement.

Conclusions

- Moderate uptake of plug-in vehicles could cause significant challenges for distribution networks if demand from recharging is uncontrolled.
- Constraints arise largely from voltage drop and unbalance, violation of transformer and cable thermal limits, increases in network losses, fault levels and issues such as harmonics and step voltage changes.
- The level of reinforcement required to accommodate plug-in vehicle demand will vary by distribution network type, for example urban versus rural networks, due to a range of factors such as differing technical design characteristics, levels of expected plug-in vehicle penetration, customer behaviour and adoption of time-of-use tariffs.
- Traditional network reinforcement, by way of substation upgrades and cable reinforcement, is likely to be increasingly inefficient in terms of accommodating the incremental and unpredictable loads expected from plug-in vehicles and other technologies such as heat-pumps.

  Further, the costs of traditional reinforcement are likely to be significantly greater compared to the capital expenditure and operational costs required to build and maintain 'intelligent infrastructure' to enable more controlled plug-in vehicle recharging.
- If future electrical distribution networks are to realise their full potential in order to support the challenges associated with the transition to low-carbon electricity, Distribution Network Operators (DNOs) will need to move away from the conventional, passive reinforcement approach towards a 'smart grid' approach encompassing a higher degree of network operational management.
- In addition to network management measures such as LV network voltage control, implementation of 'customer-side' mitigation strategies or Demand Side Management (DSM) will play a key part in the smart grid approach.

  It is estimated that, overall, the net present value (NPV) of national network reinforcement by DNOs can potentially be reduced over 2010-2050 from around £6 billion (NPV) down to £1.5 billion (NPV) by such demand-side measures, depending on the level of system intelligence implemented.

  However, the success of such measures and the effectiveness of a 'smart grid' are also reliant on effective consumer engagement, the costs of which are challenging to forecast.