opus one solutions

Creating Load & Generation Forecasts for the IDP Workflow

In Support of MERLIN 2.02

29 JANUARY 2021

Objectives

The objective of today's meeting is to align on the following:

- The methodology to generate GridOS IDP input data
- Work completed to date
- The distribution of tasks between Opus One and SSEN for Fort Williams data
- The distribution of tasks between Opus One and SSEN for Oxfordshire data
- Work estimates & timelines

Agenda

I. Methodology
- Background
- Workflow
- Inputs, Key Assumptions, Outputs

II. Work Completed:
- Steps to Accounting for Heat Pumps in Feeder Loading
- Steps to Placing EV Assets & Creating EV Schedules
- Steps to Placing PV Assets & Creating PV Schedules

III. Distribution of Tasks:
- Steps to Placing EV Assets & Creating EV Schedules
- Steps to Placing PV Assets & Creating PV Schedules
- Next Steps

Methodology

Background

GridOS IDP needs load and generation forecasts and asset schedules to utilize while performing timeseries powerflows and optimal powerflows as a part of the MERLIN IDP workflow

- The MERLIN project will consider analysis to reflect network conditions between 2026 and 2035
- IDP requires specifically formatted csv file inputs to support analyses

SSEN has decided to capitalize on data from a second innovation project completed by Regen to generate these inputs

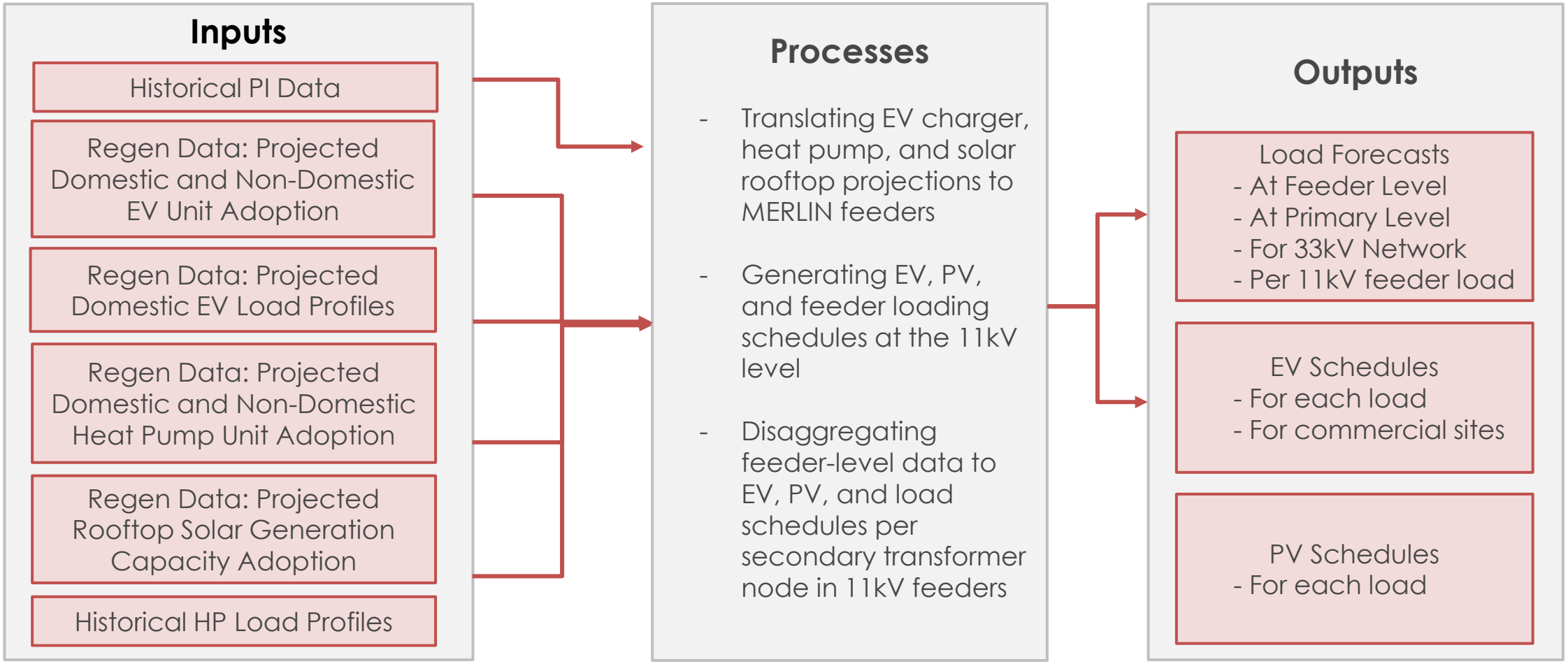
SSEN has decided to reflect two FES scenarios for the MERLIN project; Community Renewables (CR) and Consumer Evolution (CE). These are captured in reports by Regen. [1,2]

This exercise is focused on translating and formatting the Regen project data to serve as GridOS IDP inputs. This exercise also serves as the 2.02 deliverable of the MERLIN project.

1 Distribution Future Electricity Scenarios in the North of Scotland by Poppy Maltby and Frankie Mayo from Regen, 2019
2 Distributed generation and demand study Technology growth scenarios to 2032 by Poppy Maltby from Regen, 2019

Workflow

The specific steps to complete the processes outlined below are explained in following sections of this document. These build off the methodology agreed upon with SSEN.



Inputs

The Regen data used for this forecast exercise:

- Projected EV unit adoption for domestic and non-domestic EVs
- Projected domestic EV load profiles
- Projected heat pump (HP) unit adoption for domestic and non-domestic HPs
- Projected rooftop solar generation capacity

Two other historical datasets were used for this exercise:

- Historical PI loading data for each of the 11kV feeders in scope for the MERLIN project
- Historical domestic heat pump load profiles

Datasets created for this exercise have been:

- An annual solar generation profile
- A profile for non-domestic EVs
- A profile for non-domestic HPs

Key Assumptions

Key assumptions made by SSEN and Opus One in generating these datasets are:

- No load growth projected outside of those captured from heat pumps and EV chargers
- EV charger diversity factor borrowed from Regen analysis for all feeders, projects EV profiles based on number of EVs forecasted
- Loading and EV and PV adoption can be forecasted at each residential loading area proportional to the customer count at each load

Outputs

The output of this exercise includes four inputs to GridOS IDP:

1. Load forecasts for each 11kV feeder head that account for historical PI data and increased loading due to heat pumps
   - Primary substation loading and 33kV loading are calculated as a summation of downstream loadings
2. Loading schedules for domestic EVs projected on each load of each 11kV feeder
3. Loading schedules for non-domestic EVs projected on commercial sites of each 11kV feeder
4. Generation schedules for PVs projected on each load of each 11kV feeder

All IDP input files are generated at an hourly granularity for the 10-year timeframe considered (2026-2035)

The units for all IDP input files are Watts

The outputs are all generated for each of the FES scenarios:

- Community Renewables (CR)
- Consumer Evolution (CE)

Work Completed:

Steps to Accounting for Heat Pumps in Feeder Loading

Generating Merlin HP Load Forecasts (1/2)

Steps	Domestic	Non-Domestic
Correlate Each Row of HP Numbers to MERLIN_IDs	By Regen_ID	By T_ID
Aggregate Across all Correlations per MERLIN_ID	Pivot tables reporting on number of HPs per MERLIN 11kV feeder per year for both scenarios	
Create Domestic HP Load Profiles for 2018	Based on historical HP load profiles Sum of two columns 'heat_pump_input_energy_kWh' and 'heat_pump_hw_input_energy_kWh' in the file 'HeatProfileScaled'	
Create HP Load Profiles for 2019-2035	Replicate 2018 HP load profile up to 2035 For leap years, replicate load data on Feb. 22nd for Feb. 29th	Weekdays: • 12500W 6am-6pm • 4000W at all other times Weekends: • 4000W at all time
Generate HP Experienced Load for 2019-2035	For both scenarios of each feeder: For each day from 2019 to 2035, multiply the load file with the corresponding number of HPs	

Generating Merlin HP Load Forecasts (2/2)

Steps	Domestic	Non-Domestic
Convert HP Experienced Load from Half-hourly Intervals to Hourly Intervals	Convert units from kWh to Wh by multiplying loads by 1000 Multiply each half hour interval by 2 to convert to W then borrowed the top of the hour	Borrow the top of the hour
Populate Missing PI Data (Year 2019)	Use code to find missing hourly intervals and populate with load data at the same interval the week before Example: Missing 2.19 16:00, take 2.12 16:00 data Exception: If missing intervals in the first week, take next week's data	
Replicate 2019 PI Data Up to 2035	For leap years, replicate load data on Feb. 22nd for Feb. 29th	
Add HP Loads to PI Load	For every 11kV feeder and both FES scenarios, add both domestic and non-domestic HP loads to PI load on each day	
Remove HP+PI Load Data for 2019-2025	Analysis timeframe will be January 1, 2026 to December 31, 2035 to select 10-year timeframe for the MERLIN analysis	
Generate HP+PI Loads at Primary Level	For each FES scenario, generate PI+HP loads at primary level by aggregating across 11kV PI+HP loads under each primary	
Generate HP+PI Loads for 33kV Network	For each FES scenario, generate PI+HP load for 33kV network by aggregating across all primary PI+HP loads	

Generating Merlin HP Load Forecasts (2/2)

Steps	Domestic	Non-Domestic
Disaggregating PI+HP Feeder-Head Loading Data to Correspond to per Load loading based on customer counts (**Requires Excel Scripting & API scripting)**	PI + HP files account for both domestic and non-domestic HP projections so now difference will be made when allocating to loads. This assumes a somewhat equal distribution of domestic and non-domestic customers behind each secondary transformer load	
Uploading load schedules to each load on each 11kV feeder (**Requires API Scripting)**	PI + HP files account for both domestic and non-domestic HP projections so now difference will be made when allocating to loads. This assumes a somewhat equal distribution of domestic and non-domestic customers behind each secondary transformer load	

Work Completed:

Steps to Placing EV Assets & Creating EV Schedules

EV Assets & Schedules (1/4)

Steps	Domestic Off-Street	Domestic On-Street	Non-Domestic (6 types)
Correlate Each Row of EV Numbers to MERLIN_IDs	By Regen_ID	By T_ID	By T_ID
Aggregate Across all Correlations per MERLIN_ID	Pivot Table reporting on number of EVs on each MERLIN 11kV feeder for each scenario		
Aggregate Across all Types of EVs	Sum off- and on-street to report on total domestic units per MERLIN 11kV feeder, rounded to the nearest whole number		Sum across all 6 types to report on total domestic units per MERLIN 11kV feeder, rounded to the nearest whole number

EV Assets & Schedules (2/4)

Steps	Details/Assumptions
Populate Half-hourly Charging Profile for Domestic EVs	Use linear slopes between known values, and multiply profile loading by # of EVs
Translate to Experienced Daily Load	To determine load at half-hourly intervals per 11kV per year for each FES scenarios: Domestic – Use updated 7kW charger hourly forecast Non-Domestic – Assume constant 50kW for each EV
Convert Experienced Daily Load to Hourly Intervals	For both domestic and non-domestic, extract load at hourly intervals per 11kV per year for both scenarios and convert units from kW to W
Generate EV Load Data for 2019-2035	For both domestic and non-domestic EVs per 11kV per FES scenario, generate EV load data for 2019-2035 by repeating experience daily load 365 times for normal years and 366 times for leap years, resulting in 4 EV load files per 11kV feeder
Remove EV Load Data for 2019-2025	Analysis timeframe will be January 1, 2026 to December 31, 2035 to select 10-year timeframe for the MERLIN analyses
Create EV Schedules at Feeder Level	For both domestic and non-domestic EVs per 11kV per FES scenario, create EV schedules by using EV load data as real power (p) and assuming reactive power (q) to be 0, resulting in 4 EV schedules per 11kV feeder

EV Assets & Schedules (3/4)

Steps	Details/Assumptions
Create EV Schedules at Primary Level	For both domestic and non-domestic EVs per FES scenario, create EV schedules at primary level by summing across 11kV EV loads under each primary, resulting in 12 files in total
Create EV Schedules for 33kV Network	For both domestic and non-domestic EVs per FES scenario, create EV schedules for 33kV network by summing across all primary EV loads, resulting in 4 files in total

EV Assets & Schedules (4/4)

Steps	Domestic	Non-Domestic
Place EV Charging Stations on Inverlochy 11kV Feeders	Place 1 EV charging station at each node that has a load attached **(Need API scripting)**	SSEN to determine location(s) for placing EV charging station(s) - Considered maximum demand customers to determine potential locations for non-domestic EV charging stations. - Total of 58 non-domestic EV charging stations across all Inverlochy feeders – not all have been modeled since the current network models do not account for all nodes from source PSSE data
Disaggregate EV Schedules at Feeder Level Down to Per Station Schedules	Proportional to the customer count at the load that is on the same node as the EV station **(Need Excel files & API scripting)**	SSEN to determine method of distributing EV loading based on number of non-domestic EVs
Upload Per Station Schedules	**Need API scripting**	Manual

Work Completed:

Steps to Placing PV Assets & Creating PV Schedules

PV Assets & Schedules (1/1)

Steps	Details/Assumptions
Correlate Each Row of PV Capcity to MERLIN_IDs	By T_ID
Aggregate Across all Correlations per MERLIN_ID	Pivot Table reporting on projected capacity of PVs on each MERLIN 11kV feeder for each scenario
Build Generation Profile for 2026-2035	Based on "PV Profile Scotland" provided by SSEN
Generate PV Schedules at Feeder Level	For each Inverlochy 11kV feeder and each scenario, multiply the generation profile by the number of PVs to obtain real power (p) and assume the reactive power (q) to be zero
Generate PV Schedules at Primary Level	A summation of all Inverlochy 11kV feeder schedules
Place PVs on Inverlochy 11kV Feeders	Place 1 PV at each node that has a load attached **(Need API scripting)**
Disaggregate PV Schedules at Feeder Level Down to Per PV Schedules	Proportional to the customer count at the load that is on the same node as the PV **(Need Excel files & API scripting)**
Upload Per PV Schedules	**Need API scripting**

Distributing Tasks:

Steps to Updating Load Schedules

Generating Merlin HP Load Forecasts (1/2)

Steps	Domestic	Non-Domestic
Correlate Each Row of HP Numbers to MERLIN_IDs	By Regen_ID	By T_ID
Aggregate Across all Correlations per MERLIN_ID	Pivot tables reporting on number of HPs per MERLIN 11kV feeder per year for both scenarios	
Create Domestic HP Load Profiles for 2018	Based on historical HP load profiles Sum of two columns 'heat_pump_input_energy_kWh' and 'heat_pump_hw_input_energy_kWh' in the file 'HeatProfileScaled'	
Create HP Load Profiles for 2019-2035	Replicate 2018 HP load profile up to 2035 For leap years, replicate load data on Feb. 22nd for Feb. 29th	Weekdays: • 12500W 6am-6pm • 4000W at all other times Weekends: • 4000W at all time
Generate HP Experienced Load for 2019-2035	For both scenarios of each feeder: For each day from 2019 to 2035, multiply the load file with the corresponding number of HPs	

Generating Merlin HP Load Forecasts (2/2)

Steps	Domestic	Non-Domestic
Convert HP Experienced Load from Half-hourly Intervals to Hourly Intervals	Convert units from kWh to Wh by multiplying loads by 1000 Multiply each half hour interval by 2 to convert to W then borrowed the top of the hour	Borrow the top of the hour
Populate Missing PI Data (Year 2019)	Use code to find missing hourly intervals and populate with load data at the same interval the week before Example: Missing 2.19 16:00, take 2.12 16:00 data Exception: If missing intervals in the first week, take next week's data	
Replicate 2019 PI Data Up to 2035	For leap years, replicate load data on Feb. 22nd for Feb. 29th	
Add HP Loads to PI Load	For every 11kV feeder and both FES scenarios, add both domestic and non-domestic HP loads to PI load on each day	
Remove HP+PI Load Data for 2019-2025	Analysis timeframe will be January 1, 2026 to December 31, 2035 to select 10-year timeframe for the MERLIN analysis	
Generate HP+PI Loads at Primary Level	For each FES scenario, generate PI+HP loads at primary level by aggregating across 11kV PI+HP loads under each primary	
Generate HP+PI Loads for 33kV Network	For each FES scenario, generate PI+HP load for 33kV network by aggregating across all primary PI+HP loads	

Updating Load Schedules (1/1)

Steps	Responsible Party – Fort William	Responsible Party – Oxfordshire
Correlate Each Row of HP Numbers to MERLIN_IDs	Opus One - Complete	Opus One
Aggregate Across all Correlations per MERLIN_ID	Opus One - Complete	Opus One
Create Domestic HP Load Profiles for 2018	Opus One – Complete	Opus One
Create HP Load Profiles for 2019-2035	Opus One - Complete	Opus One
Generate HP Experienced Load for 2019-2035	Opus One - Complete	Opus One

Updating Load Schedules (1/1)

Steps	Responsible Party – Fort William	Responsible Party – Oxfordshire
Convert HP Experienced Load from Half-hourly Intervals to Hourly Intervals	Opus One - Complete	Opus One
Populate Missing PI Data (Year 2019)	Opus One - Complete	Opus One
Replicate 2019 PI Data Up to 2035	Opus One – Complete	Opus One
Add HP Loads to PI Load	Opus One - Complete	Opus One
Remove HP+PI Load Data for 2019-2025	Opus One – Complete	Opus One
Generate HP+PI Loads at Primary Level	Opus One – Complete	Opus One
Generate HP+PI Loads for 33kV Network	Opus One - Complete	Opus One

Updating Load Schedules (1/1)

Steps	Responsible Party – Fort William	Responsible Party – Oxfordshire
Disaggregating PI+HP Feeder-Head Loading Data to Correspond to per Load loading based on customer counts (**Requires Excel Scripting & API scripting)**	SSEN- complete	SSEN
Uploading load schedules to each load on each 11kV feeder (**Requires API Scripting)**	SSEN- in progress	SSEN

Distributing Tasks:

Steps to Placing EV Assets & Creating EV Schedules

EV Assets & Schedules (1/4)

Steps	Responsible Party – Fort William	Responsible Party – Oxfordshire
Correlate Each Row of EV Numbers to MERLIN_IDs	Opus One – Complete	Opus One
Aggregate Across all Correlations per MERLIN_ID	Opus One – Complete	Opus One
Aggregate Across all Types of EVs	Opus One – Complete	Opus One

EV Assets & Schedules (2/4)

Steps	Responsible Party – Fort William	Responsible Party – Oxfordshire
Populate Half-hourly Charging Profile for Domestic EVs and Change to Hourly	Opus One – Complete	Opus One
Translate to Experienced Daily Load	Opus One – Complete	Opus One
Generate EV Load Data for 2026-2035	Opus One – Complete	Opus One
Create EV Schedules at Feeder Level	Opus One - Complete	Opus One

EV Assets & Schedules (3/4)

Steps	Responsible Party – Fort William	Responsible Party – Oxfordshire
Create EV Schedules at Primary Level	Opus One – Complete	Opus One
Create EV Schedules for 33kV Network	Opus One – Complete	Opus One

EV Assets & Schedules (4/4)

Steps	Responsible Party – Fort William	Responsible Party – Oxfordshire
Place EV Charging Stations on Inverlochy 11kV Feeders	SSEN – Complete	SSEN
Disaggregate EV Schedules at Feeder Level Down to Per Station Schedules	SSEN – Complete	SSEN
Upload Per Station Schedules	SSEN – In Progress	SSEN

Distributing Tasks:

Steps to Placing PV Assets & Creating PV Schedules

PV Assets & Schedules (1/2)

Steps	Responsible Party – Fort William	Responsible Party – Oxfordshire
Correlate Each Row of PV Capcity to MERLIN_IDs	Opus One – Complete	Opus One
Aggregate Across all Correlations per MERLIN_ID	Opus One – Complete	Opus One
Build Generation Profile for 2026-2035	Opus One – Complete	Opus One
Generate PV Schedules at Feeder Level	Opus One – Complete	Opus One
Generate PV Schedules at Primary Level	Opus One – Complete	Opus One

PV Assets & Schedules (2/2)

Steps	Responsible Party – Fort William	Responsible Party – Oxfordshire
Place PVs on Inverlochy 11kV Feeders	SSEN – In Progress	SSEN
Disaggregate PV Schedules at Feeder Level Down to Per PV Schedules	SSEN	SSEN
Upload Per PV Schedules	SSEN	SSEN

Next Steps

The next steps are to:

- Complete input data preparation for Fort Williams network
  - SSEN to disaggregate EV, PV, and load forecasts generated to per load inputs
- Complete baseline network preparation for Fort Williams network
  - SSEN to create per load EVs and PVs
  - SSEN to upload schedules to EVs, PVs, and loads
- Prepare input data for Rosehill 11kV networks in Oxfordshire:
  - Opus One to translate Regen data for MERLIN feeders for EVs, PVs, and HPs
  - Opus One to create aggregate schedules for
- Complete baseline network preparation for Oxfordshire network
  - SSEN to create per load EVs and PVs
  - SSEN to upload schedules to EVs, PVs, and loads

For questions and follow-up please contact

Lobna El Gammal

lelgammal@opusonesolutions.com
289-242-7607

Siyu Sun

ssun@opusonesolutions.com
647-937-9508