

Milestone 2

1.07 GridOS IDP Configuration and Development

By **Gerhard Walker** and **Hisham Omara**

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Scottish & Southern
Electricity Networks



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1 Executive Summary

Traditionally, Distribution Network Operators (DNOs) have used the physics-based Power Systems Analysis to assess a power system's response to events in transient, dynamic and static time scales. However, to deliver a sustainable smart grid for consumers, understanding the effect economics has on the physics, and how the physics constrains or facilitates the economics, will become critical- this is known as Power System Economics.

DNOs are transitioning to Distribution System Operators (DSOs) to enable local energy marketplaces to function effectively. Yet the current portfolio of industry projects does not solve the problem of managing the ever-variable value of services and associated conflicts which will become an increasing factor as Distributed Energy Resources (DER) increase.

One of the key deliverables of the Merlin project is to develop learning and tools that will allow planners to pivot away from worst case scenario assessments to an approach that captures the economic and technical details of operational realities within planning. These realities include the assessment of the economic and technical viability of flexibility services and the impact on their real time operation against traditional solutions. As such the financial management tool (FMT) would allow users to:

Assess the system for the entire study period, at each study interval (i.e. hourly or 15 minutes), for every asset and every node for GridOS IDP will be to achieve a sub-set of capabilities of the FMT outlined in the CGI report which was completed as part of the MERLIN project¹.

This report is organized into two chapters, these chapters cover the following aspects:

Chapter 1: GridOS IDP Scope: This section details the objective of the Financial model tool, the data requirements and provides a detailed process flow walkthrough

Chapter 2: Detailing the Economic Modeling: This section provides detail around the components of the financial modeling with GridOS IDP

¹ The report can be found at:

2 GridOS IDP Tool

The existing planning methodologies predominately use worst-case-scenario interconnection studies avoiding the complexities of technoeconomic analyses that reflects the realities of real time operations. Furthermore, these assessments are technical “work-arounds” such as a detailed analysis on select feeders and extrapolating results to others, or a simplified screening analysis on all feeders that do not capture the full detail of the network. These solutions also do not provide situational awareness, monetized value of DER assets or accurately account for the input uncertainty. Some solutions provide data rationalization and data visualization but lack a built-in power flow tool or an in-depth system analysis. The existing power flow tools can either run as a static tool for planning and operation processes but are heuristics or rules-based systems which are not sufficient in terms of flexibility, configurability, and reaching global optimality. For distribution systems with DER and Distribution Automation (DA) penetration, only a 3-phase AC unbalanced model should be used. Any type of balanced and DC approximation that does not consider the unbalanced nature of the grid, or that neglects the real and reactive components of grid behaviour, will be insufficient.

Furthermore, existing tools are limited in their ability to quantify the technical performance of DER and flexibility assets, as well as the locational net benefit analysis for DER valuation which is becoming a critical consideration for planning future grid stability. As such the MERLIN project will be deploying GridOS Integrated Distribution Planning to provide the ability to plan for capital assets while also understanding the techno-economic impacts of DERs. In GridOS IDP, users can quantify, evaluate, and compare potential investment scenarios to reveal the lowest cost and/or highest customer value options.

2.1 The GridOS IDP Approach

GridOS IDP will allow planners to quantify and evaluate potential investment scenarios (network reconfiguration, flexibility procurement, expansion strategies, and non-wires alternatives) based on asset benefits, by type, capacity, location, and time. Furthermore, GridOS IDP be able to determine the different cost components of each potential solution, assess their technical viability at addressing system needs, comparing the solutions to reveal the lowest cost and/or highest customer value options.

2.2 Data Requirements

To facilitate accurate modeling of investment scenarios, the following data sets would be required as inputs into GridOS IDP:

Table 1: GridOS IDP Data Inputs

Variable	Description	Type of Input
Asset Age	Construction date of assets to inform age of asset	Date entry on assets, bulk upload
Asset Health Metric	SSEN determined value on assets health	Integer value 1-5 on assets, bulk upload
Probability of Failure	Determine how often assets fail based on variables	Formula entry in the Equipment Library
Time to Restore	Determine outage duration in case of failure	Time entry in the Equipment Library

Cost of supply loss	Regulated cost of losing power to a customer	Value entry in the Equipment Library
Cost of voltage violation	Simulated Financial risk assessment for utility	Value entry in the Equipment Library
Cost of rating violation	Simulated Financial risk assessment for utility	Formula entry in the Equipment Library
Load Criticality Index	Importance of certain load types	Value entry in the Equipment Library
Contract Information	Outlines contract costs on assets	Value entry on assets
Cost of System Const.	Standardized construction costs from SSEN	Value entry in the Equipment Library
Time to Construct	Standardized time to construct an asset type	Time entry in the Equipment Library
Network Model	Electrical connectivity model	Common Information Model (CIM) upload / import
Feeder Schedule	Historic or forecasted feeder SCADA readings in kW	File upload
Asset Schedules	e.g. AIM where present as kW/kvar time series	File upload
OPEX Cost	OPEX cost per year for specific assets	Value entry in the Equipment Library
Bulk System CO2	Time series CO2 emissions for the bulk system	File upload
CO2 Cost	Time series cost of CO2 emissions	File upload
Societal Costs/Benefits	Externally determined annual society cost/benefit	Value entry in the Equipment Library

2.3 Process Flow

This section outlines a process walkthrough of how a user would be able to utilize the GridOS IDP to determine the best course of action to mitigate future system constraints.

1. Setting up the models

This initial, one-time step includes the distribution planners setting up the network models and providing all the required secondary information to the tool.

a. Importation of network model and validation of data

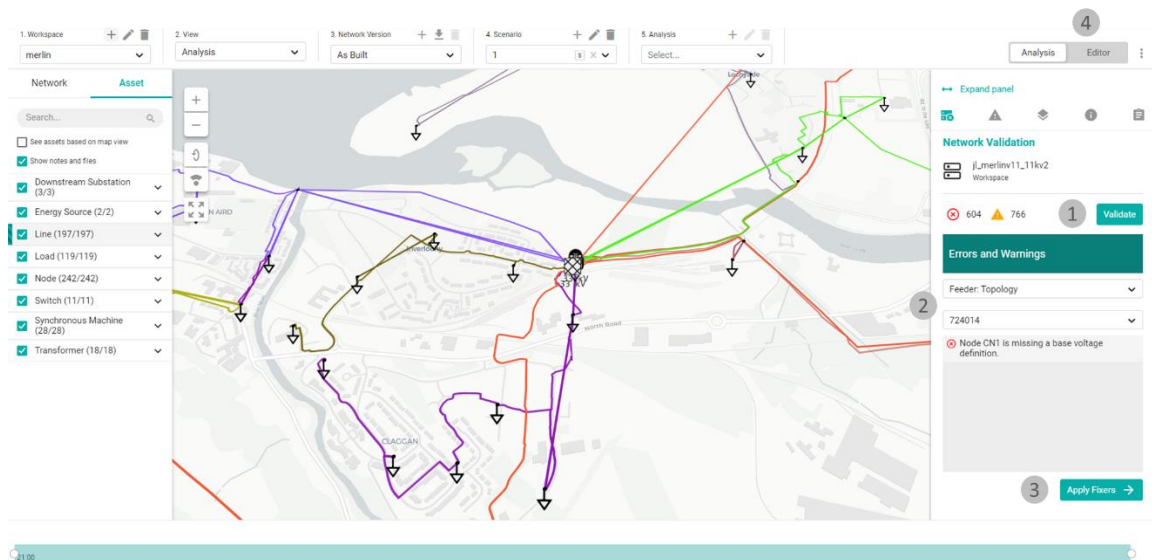


Figure 1: Setting up network models

1. Validate to determine errors in the network data model
2. Detail the location, asset and missing/erroneous data
3. Apply fixes that cover the most common issues
4. Edit the network model to address network errors

b. Setting up parameters for flexibilities and network assets

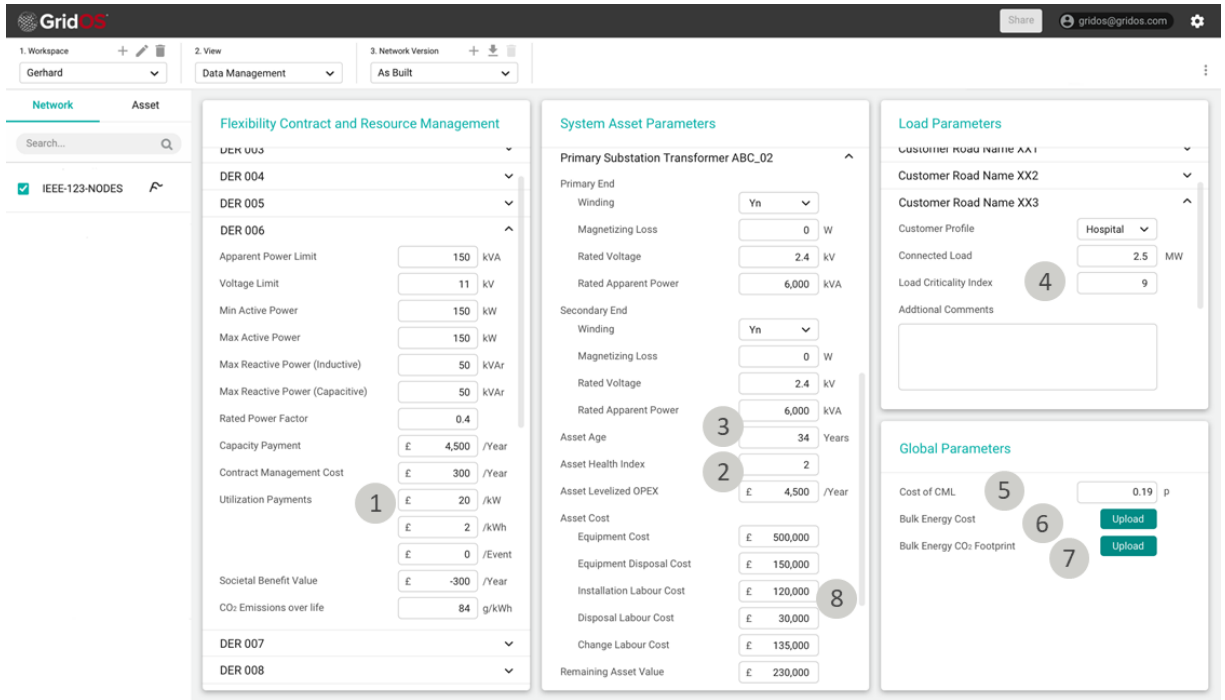


Figure 2: Set up parameters for flexibilities & network assets

1. Contract information for existing assets: Tracks cost of existing, or new contracts over the simulation horizon and can be configured individually per asset
2. Asset Health Index: Identifies assets nearing end of life for remaining value and rate base increase calculations on project costs
3. Asset Age: Identifies assets nearing end of life for remaining value and rate base increase calculations on project costs
4. Asset Criticality: Identifies penalty multipliers for critical loads
5. Supply Interruption Cost: Customer minutes lost cost and Customer interruptions?
6. Cost of Energy: Time series cost of bulk energy per kWh
7. CO2: Time Series CO2 emissions for bulk energy as well as CO2 cost
8. Capital Cost: Levelized cost information for utility assets used for determining total capital cost of upgrade projects

c. Creation of Baseline

The baseline represents the unmodified simulation looking at the as is, or as projected system condition. Planners perform this analysis on the as built model with the respective scenarios and can then determine, in full detail, when, where, how often, and by how much a system is constrained. Multiple baselines can be set for e.g. different reference days, or different future scenarios such as a low and high load growth scenario.

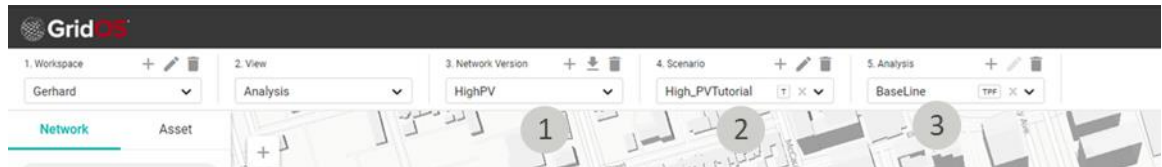


Figure 3: Creation of baseline

- | | |
|--|---|
| <p>1. Different Network Versions: Allow the planner to define different physical alterations to the network, such as new DER developments</p> <p>3. Different Analysis: Provide the planner with the ability to run a wide array of solutions per network version and scenario combination</p> | <p>2. Different Scenarios: Allow the planner to define forecasts / back casts for the network version, such as reference days, high or low load scenarios</p> |
|--|---|

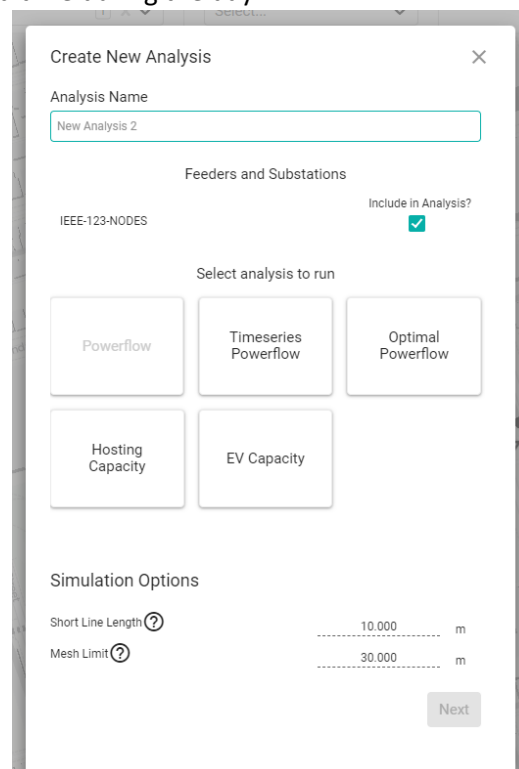
2. Assess the network

a. Selecting the Analysis

When running analysis, GridOS provides a wide variety of options that can be chosen depending on the objective. E.g., if no flexible or dispatchable resources are present, a time series power flow is chosen. If there are flexible resources that serve some purpose, such as peak shaving, then optimal power flow is chosen.

GridOS IDP offerings six (6) key analysis tools:

1. Standard Power Flow (snapshot)
2. Time Series Power Flow using the forecast
 - The user can select start and end date of the time series (up to 10 years)
3. Optimization Problems using the optimal power flow engine in separate analysis as needed
 - Peak Shaving
 - Loss Optimization
 - Conservation Voltage Reduction
 - Economic Optimization
 - Determine the operational cost impacts of the non-wires alternative (NWA) (Q&M, energy, material etc.)
4. Demand Response, which allows the simulation of load management events
5. Hosting Capacity, which provides range of tools to analyse the system's ability to absorb distributed generation resources
6. EV Capacity to determine the maximum available charging capacity at any point on the network and time during the day.



Create New Analysis

Analysis Name
New Analysis 2

Feeder and Substations
IEEE-123-NODES

Include in Analysis?
☒

Select analysis to run

Powerflow
Timeseries Powerflow
Optimal Powerflow
Hosting Capacity
EV Capacity

Simulation Options

Short Line Length 10,000 m
Mesh Limit 30,000 m

Next

Figure 4: Select the analysis

b. Determining Forecasted System Violations

One key requirement of GridOS IDP is to understand how often certain flexibilities would be utilized to determine if there would be a business case for a flexible solution compared to a non-wire alternative. GridOS – IDP provides unique capabilities when tracking and identifying system constraints by allowing a user to determine, when, how often, for what duration, what magnitude, and which parameter is violating on the system. The user can use both the intuitive time bar to find violations over time, as well as the GIS map to find them on the network.

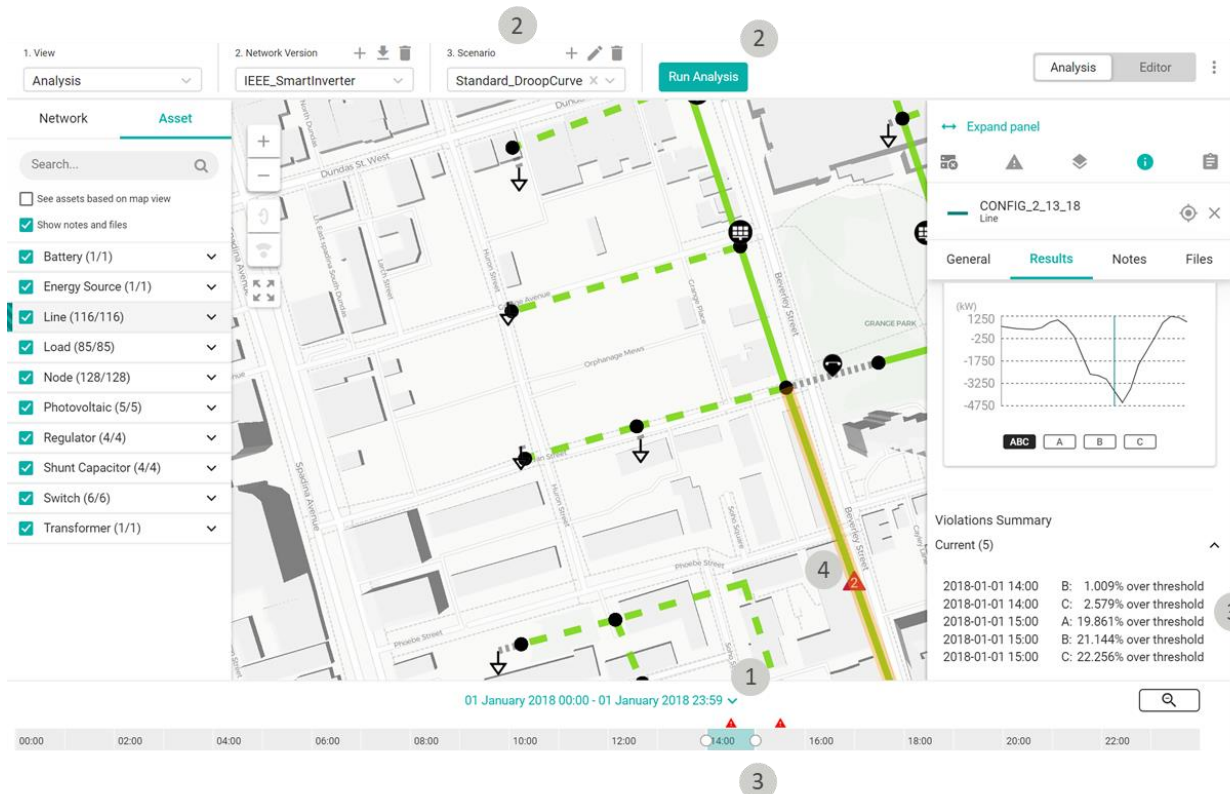


Figure 5: Tracking Violations over Time and Space

1. Determine timeframe (1 hour – 10² years) for analysis
2. Identify scenario and type of analysis to run
3. Identify the number, time, location, type and duration of violation/constraint(s)
4. Visualize constraints/violations and analysis results

² GridOS IDP can run simulations >10 years with the limitation being set by the length of time the simulation will run for.

3. Creation of Solutions

a. Creation of Solutions

Once the constraints are identified, the network model editor is used to define viable system upgrades that remove the violations. The planner can construct multiple different traditional solutions which are saved in parallel network versions for later comparison.

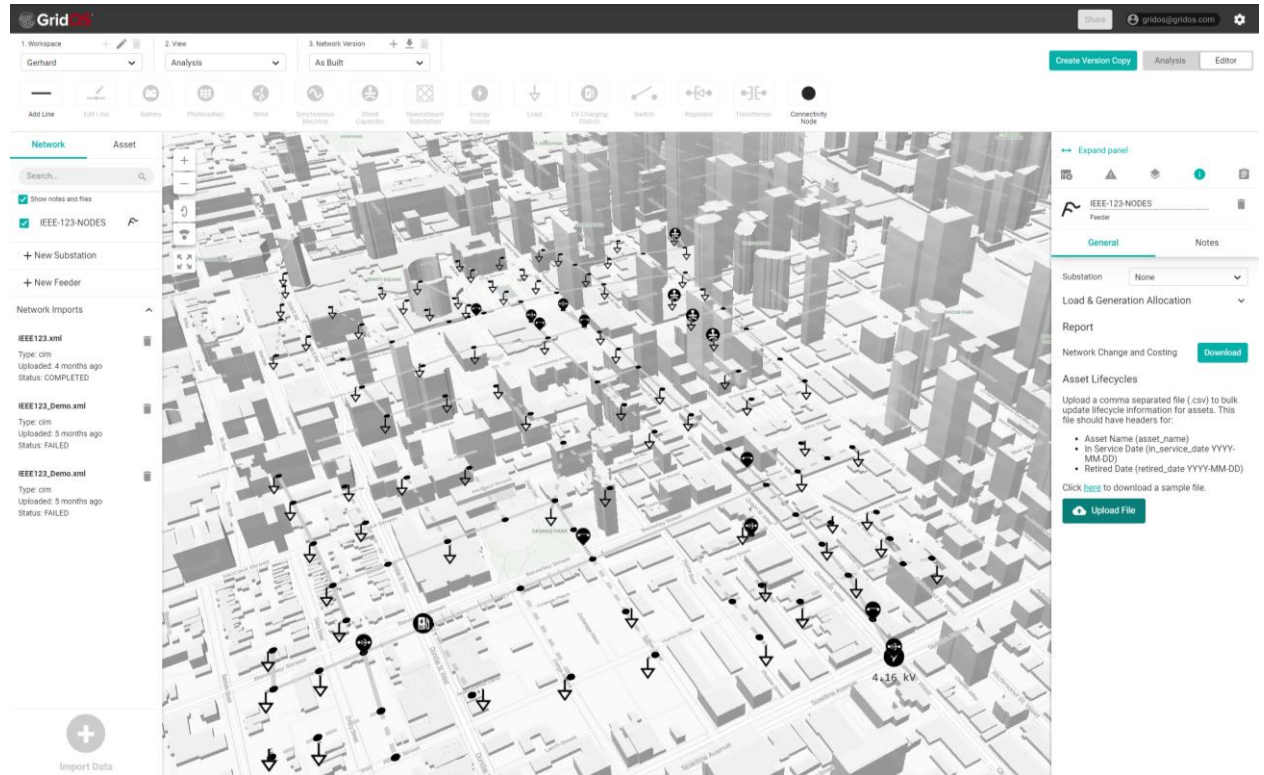


Figure 6: Network Model Editor Mode

b. Determining cost of addressing the constraint(s)

The cost of addressing the constraint(s) is determined by the capital cost, including both labour and materials, required to deploy new infrastructure to mitigate the constraints on the system. The planner engages the network editor mode which provides the ability to make changes to the distribution system while tracking expected project cost, as well as net present value and final energization date of said project. A formula editor for net present value, as well as value of deferral, provide additional economic analysis options to the user.

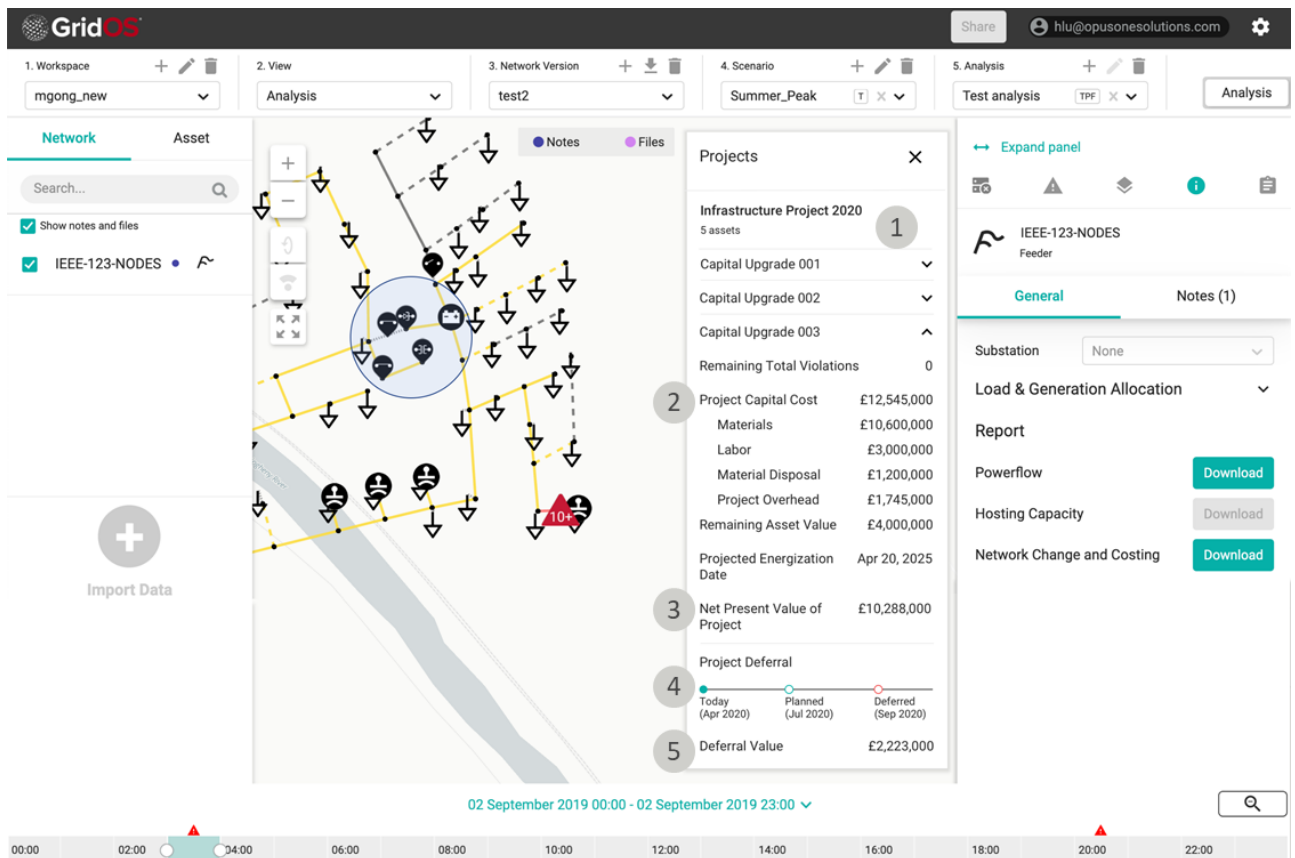


Figure 7: Determine cost of constraints

1. Construction Projects Planned: Project costs are estimated through the editor as planners plan system upgrades
2. Total cost of project with sub-categories: Shows itemized cost for projects
3. Net present value of projects: Net present value reference to the original completion date
4. Option of deferring projects: Allows the user to change the completion date
5. Value of project deferral: Computes the value of deferral as a difference in net present value after deferring the project

c. Solution Optimization

GridOS – IDP accesses the GridOS Optimization Engine (OE), which allows the tool to create optimal dispatches for flexibilities of all types and classes around a variety of optimization objectives, such as peak shaving, loss optimization, voltage optimization, or economic dispatch optimization. Throughout this project, all secondary low voltage connected flexibilities are treated as equivalent resources on the 11 and 33-kV systems. This enables GridOS – IDP to perform analysis of power systems with flexibilities and provide planners with visibility into when and how much DER are utilized to mitigate system constraints. Planners use this information to make determinations of the financial feasibility of such assets. Furthermore, this provides a planner with a technical evaluation of whether a chosen flexibility solution will be able to meet the requirements set forth by the constraint, or if more flexibility, or a traditional upgrade are required.

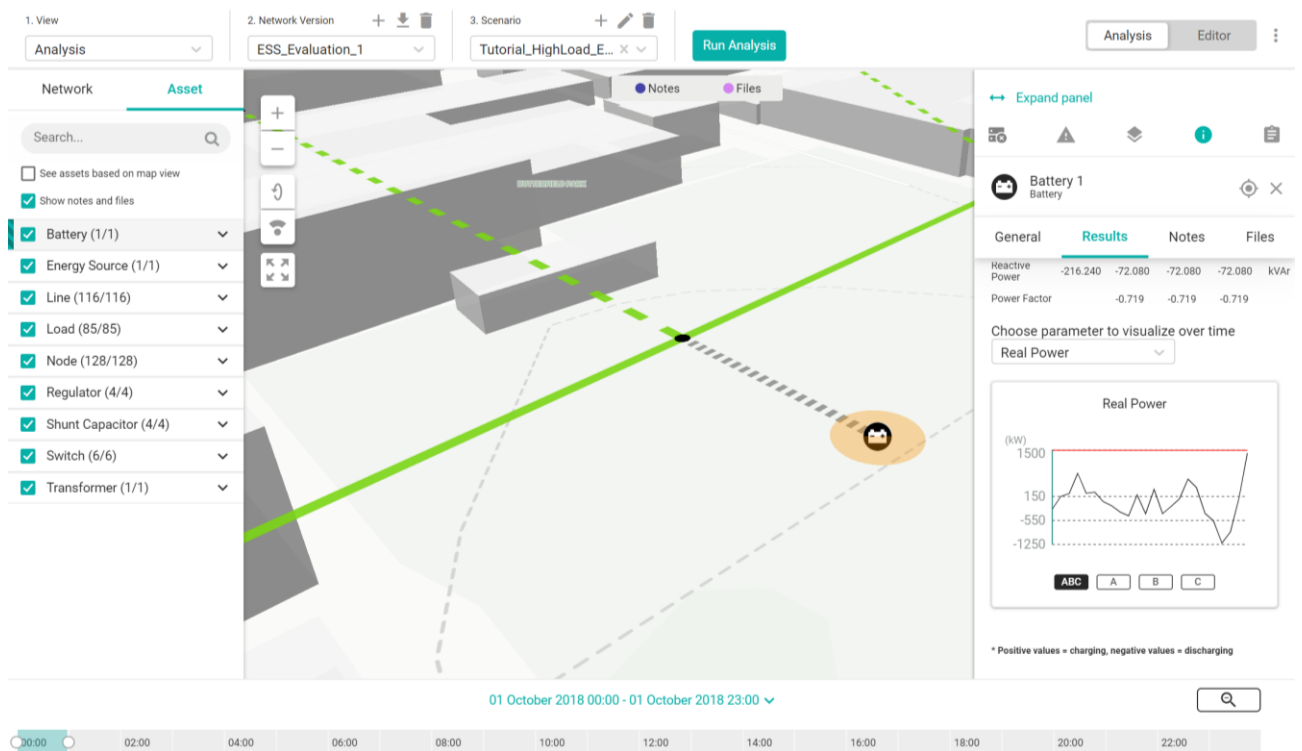


Figure 8: Optimized Battery Dispatch to Mitigate System Constraints

4. Solution Assessment and Comparison Solutions

a. Solution Assessment

Once all solutions are in place, the tool performs the required analysis and provides the user with an overview in the results comparison. The results comparison allows side by side comparison of a variety of parameters for different network versions, scenarios, and analysis run.

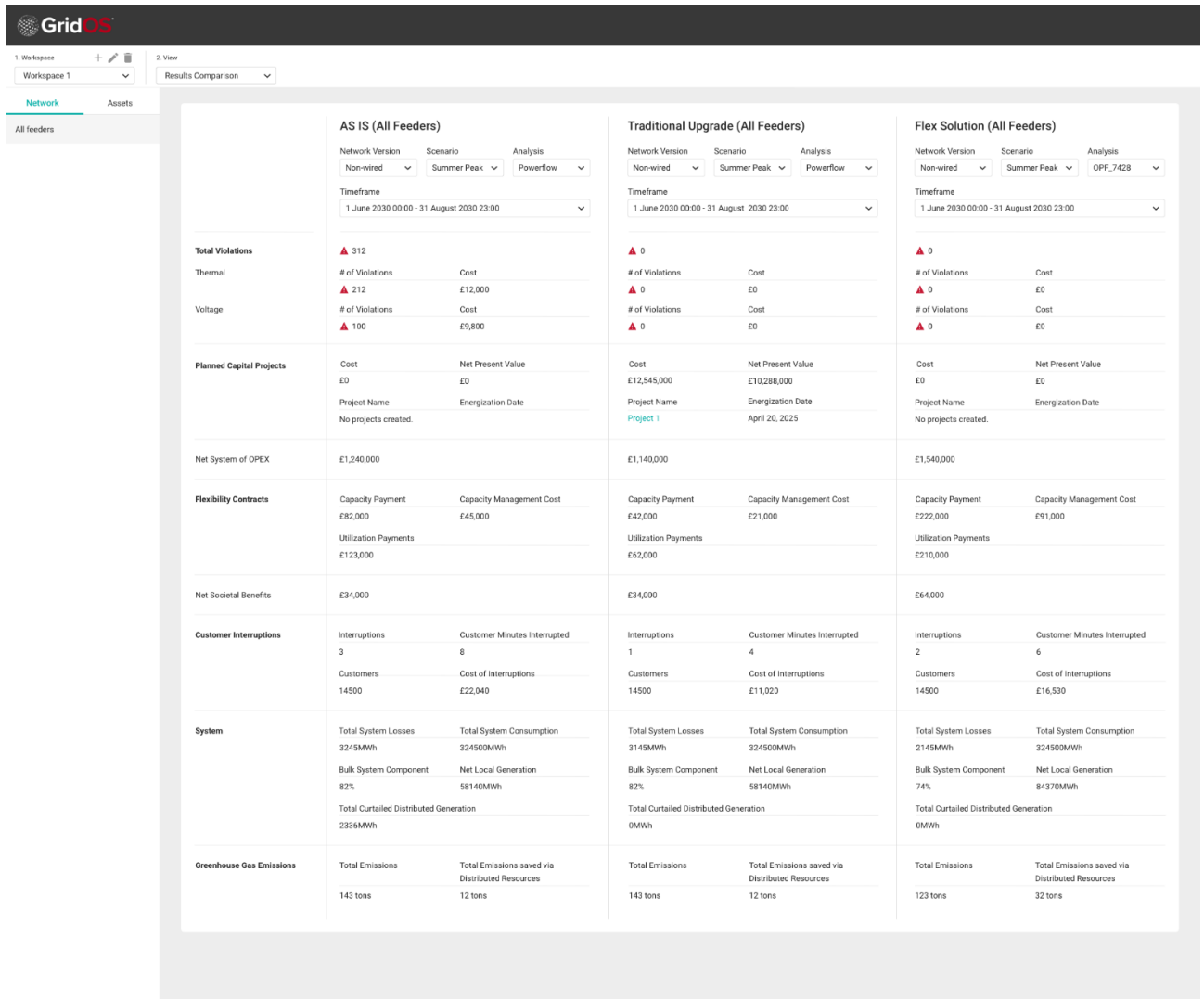


Figure 9: General Overview of Compared Data

3 Detailing the Financial Modeling

This section provides an in-depth view of the key data constructs, financial modeling mechanisms, modeling capabilities and optimization methods that GridOS IDP will facilitate.

3.1 Data Supporting the determination of cost of running the system

To enable the decision-making process, GridOS – IDP will be undertaking financial modeling that would include data sets that inform the financial viability of the different solutions. The following outlines the data sets that will be added to the tool and how they will contribute to the decision-making process. All formulas described in these sections are kept generic as the tool will enable the usage of a formula editor to modify equations as needed.

- I. **Asset Health Metric:** The asset health metric will be assignable to each asset in a value range from 1-5, with 1 representing excellent conditions, and 5 heavily deteriorated conditions. The health metrics will be used during project costing and for the reliability calculations. α will be an asset specific parameter that is visible and editable when selecting an asset. It is used for reporting of construction project costs as well as overall failure probabilities.
- II. **Probability of asset failure:** All assets will be associated with a respective average probability of failure. Each asset will have a base failure component which is influenced by the assets age (ϑ), health metric, and loading condition in percent of rating $A_{\%}$ and manifests itself in the total failure probability per time interval of $\delta(t)(\vartheta, \alpha, A_{\%}(t))$ at time t and can be edited in a formula editor. δ Will be maintained in the Equipment Library (EQL) and the reported total number of failures and overall outage minutes will be visible in the results comparison over the duration of the simulation.

$$A_{\%}(t) = \% \text{ over threshold at timepoint } t$$

- III. **Time to restore:** All assets will be associated with an average time to restore after an outage, providing a duration of an outage should an asset fail based on the probability of asset failure. The time to restore is represented by τ and maintained in the EQL. It is used in calculating the total outage time in combination with the probability of asset failure.
- IV. **Cost of supply interruption:** For all load in the tool will be upgraded to include a cost of supply interruption. In combination with the probability of outage and restoration time provides an understanding of the cost the utility will incur in no supply fines E_{CI} and E_{CMI} will be maintained in the EQL. E_{CI} and E_{CMI} multiplied with the time to restore and probability of failure informs the expected cost of supply interruptions.
- V. **Cost of rating violations:** By associating a leveled cost of rating violations based on the impact on asset life, the cost of a constraint can be more clearly understood in combination with impact of reliability. $\gamma_{rating}(A_{\%})$ is stored in the EQL and can be edited in a formula editor. The cost of a rating violation is based on the $A_{\%}$ and can be edited using the formula editor.
- VI. **Load Criticality Index:** Load classes can be given a ranking of 1-4 to determine their criticality, e.g. 1 representing residential and 4 hospital or other critical installations. Δ will be a parameter maintained in the tool's equipment library. The load criticality index serves only for visualization purposes as planner observe the network.
- VII. **Societal Cost:** An asset-based cost σ information per year that a user can enter. This represents external parameters reflected as societal cost, such as noise pollution through a generator that is deployed as a flexibility solution. The societal cost gets tallied up over all assets that have a value and is shown as a separate line item (not included in the operating cost) in the results comparison.

Societal cost line items that can be added to an asset are all in £/year (positive and negative) and include:

- a. Community Generation Credit
- b. Net Avoided Air Pollutants
- c. Avoided Water Impacts
- d. Avoided Land Impacts
- e. Net Non-Energy Benefits
- f. Net Non-Energy Costs

VIII. Asset OPEX Cost: A line item on all asset types in the EQL per year representing the total cost of utility operational expenses (OPEX) incurred through service and maintenance *OPEX*. Talled up in the end to be included in the total cost to run the system.

IX. Contract Information: Each asset already under contract can be updated to include:

- a. Annual Contract Cost: Fixed value paid to the DER every year
- b. Annual Administration Cost: Fixed value added on contract cost, internal utility administration cost
- c. Event Contract Cost: Fixed value paid to the DER per event
 - i. kWh: Event cost as £/kWh value
 - ii. hours: Event cost as a £/h value in which the asset is called
 - iii. Call: Event cost as a £/call value each time the asset is called

This provides the user and understanding of how much resources must be allocated to existing contracts. ω is maintained on a per asset basis. ω needs to be associated with demand response assets or DERs.

Total Cost of Running a System (excluding energy cost)

$$\begin{aligned}
 &= \sum_{\text{All intervals}} \left[\sum_{\text{All Assets}} (\delta * \tau * E_{CMI} + \delta * E_{CI} + OPEX) \right. \\
 &\quad \left. + \sum_{\text{All Nodes with Rating Violations}} (\gamma_{rating}(A_{\%})) + \sum_{\text{All Assets with Existing Contracts}} (\omega) \right]
 \end{aligned}$$

3.2 Determining the cost of an Upgrade

GridOS – IDP includes a several evaluation mechanisms that help planners streamline the data above into coherent information that allows them to make decisions.

- I. **Cost of system upgrades:** The existing capability to track changes for project costing will represent the system upgrade cost. $E_{upgrade}$ and will be maintained in the Equipment Library.
- II. **Construction Projects:** Planners will be able to specify which changes belong to an individual project, allowing them to plan multiple, independent construction projects and report on each. This capability will reside in the Editor, individual project costs, start dates, and completion dates will be shown in the results comparison. Projects will also play a key role in valuing deferral of said projects under D.III, which will also reside in the Result Comparison View. In the results comparison, projects show their cost and net present value.

- III. **Time to construct:** The Equipment Library in GridOS will include a time to construct parameter for all asset types allowing planners to determine the latest possible start date on a project that still allows them to achieve the required energization date.
- IV. **Net Present Value:** A user can set a formula for the tool to calculate a net present value of projects on the results comparison between the current date (computer) and the completion date of the project.

3.3 Modeling and Analysis

- I. **Sub Hourly Simulations:** The GridOS – IDP tool supports simulations to regular time intervals down to 1 minute with a step size as a multiple of 1 minute for capacity planning. This will allow the usage of data which is available at a higher granularity than 1 hour.
- II. **Minimize Constraint Optimization Objective:** The optimization engine within GridOS contains an objective function that provides minimal required dispatch of flexibilities to remove system constraints. This will provide an understanding of how often planned flexibilities will need to be activated to minimize system constraints. As a result, with the total cost of upgrade, or value of deferral, a value per flexibility call can be derived. This information can then be used by a planner to determine the long-term contract set up for the flexibilities. The resulting dispatch of assets is used in combination with the contract information to calculate the resulting utilization payments.
- III. **Demand Response (DR) Assets:** GridOS – IDP will provide the ability to optimize them as part of a flexibility solution to reduce system constraints. DR assets will present as two types, load reducing and load shifting. Both types of assets will allow the specification of a minimum energy consumption during a day to mirror customer requirements of the asset.
- IV. **EV Chargers:** GridOS IDP will model both AC and DC chargers as optimizable (flexible) assets. EV charger models ingest traffic information for charging simulation, such as arrival and departure time, state of charge, charging power, and other vehicle parameters. This allows GridOS to simulate both unmanaged and fully managed/optimized charging.
- V. **Combined Heat and Power (CHP) Resources:** GridOS IDP will model CHP as optimizable (flexible) assets. The CHP asset will be based on the synchronous generator model with the addition that the user can put it in a “heat driven” mode, specifying a minimum heat output for the day.
- VI. **Asynchronous Loads and Generators:** GridOS IDP will model Async Loads and Generators as optimizable (flexible) assets. This item requires further clarification with SSEN during the project as to precisely what these models represent and how they should function.
- VII. **Run of the River Hydro Plants:** GridOS IDP will model to include Hydro Plants as optimizable (flexible) assets. Run of the River (RoR) Hydro Plants present as synchronous generators with no limitations of how little or how much they generate besides physical limitations of the asset.
- VIII. **CO₂ Emissions :** In order to determine CO₂ savings of a solution tracking of CO₂ cost of energy at the substation needs to be included by upgrading the existing capabilities of the tool to track time series cost of kWh, kVarh, kW, and kVar to include a g/kWh line. Furthermore, the following assets will be given a g/kWh CO₂ cost as a fixed value in the Equipment Library.
 - a. **PV Systems**
 - b. **Wind Systems**
 - c. **Sync Generators**
 - d. **Hydro Plants**
 - e. **Combined Heat and Power Plants**

The results comparison will be upgraded to include a line item of “total CO₂” emissions for the currently selected network version, scenario, time range, and analysis.

3.4 Determining the cost of an Upgrade

- I. **Reference Days:** To facilitate the effective use of reference days as a method to evaluate the system impact and to reduce simulation time, GridOS IDP will allow the user to “stitch together” certain scenarios as reference days to yield a total year of time series data. As such, in the results comparison, a user will have the ability to combine scenario results of the same network version with multipliers before each scenario. Information from the results comparison page will then be shown as the sum of all scenarios with their multipliers. E.g. 5x Workday Scenario+ 1 Saturday Scenario+ 1 Sunday Scenario= 1 Week Scenario. The new, stitched-together scenarios only include the results comparison data.
- II. **Advanced Results Comparison:** The results comparison will include:
 - a. Probability of Supply Failure for the observed network
 - i. CMI total
 - ii. CI total
 - b. Total Cost of Supply Failure
 - i. Cost of CMI total
 - ii. Cost of CI total
 - c. Cost of rating violations total
 - d. Cost of contracts
 - i. By total utilization payments
 - ii. By total availability payments
 - iii. By total administration cost
 - e. Cost of project
 - i. Total project cost
 - ii. Present net Value of total project cost
 - f. Total system losses
 - g. Total consumption
 - i. From Bulk System
 - ii. From Bulk System Net
 - iii. From Local generation
 - h. Total curtailed generation due to constraints (Wind, PV, Sync Gen, CHP, Hydro)
 - i. Total Societal Cost by Type
 - j. Total OPEX Cost
 - k. Total CO2 emission
 - i. From Bulk
 - ii. From Local
 - iii. CO2 emission cost total
 - iv. CO2 emissions saved through local generation
 - v. COR emission cost saved through local generation
- III. **Method to Determine Value of Deferral:** The existing results comparison will allow users to defer a construction project. The value that comes from deferring said project will be the foundation to determine how much resources can be made available for flexibilities that might defer the project. The user will have the ability to define how said value is calculated using a formula input with month deferral (t) as a variable.

$$E_{Deferral}(t)$$
- IV. **Remaining Value of Replaced Assets:** When upgrading an asset to prevent a system constraint, new capital is injected into the system at an earlier time than originally intended (end of life of the asset). To represent the difference between system upgrade cost and increased asset base of the utility, the newly injected capital into the capital base of the utility must be calculated. This is done

by determining the remaining value of the replaced assets as a function of asset health metric α and asset age ϑ using the formula editor.

$$E_{upgrade}(\alpha, \vartheta)$$

- V. **Total Solution Cost:** The results comparison will provide a total solution cost for each scenario, which will be made up of:
- Cost of Running the System** before and after a project
 - Cost of Projects** including a deferral of projects

3.5 General Improvements

- I. **Formula Editor:** To enable customer interaction with certain value calculations, e.g. the cost of constraint upgrades while considering asset age and health of the unit being removed, the tool will be equipped with a basic formula editor.

4 Appendix A: Flexibility Service Valuation Mechanisms

The below table refers to the value streams considered as part of the Merlin project and addressed in the report “1.06 Flexibility Valuation Mechanism”. This table is a living document may be updated as the project progresses. There are four valuation mechanisms: Proposed Short Term Flexible Service Valuation (yellow), Possible Future Flexible Service Valuation (blue) and Possible Future Plus Flexible Service Valuation (green) and Alternative Value Stream Options (red).

For more detail on these value streams please refer to report “1.06 Flexibility Valuation Mechanism”. Table 2 provides an overview of the different value streams and the monetary valuation components associated with them. The items currently modeled as part of the project are referenced. Further detail on the Valuation mechanism can be found in in the report “1.06 Flexibility Valuation Mechanism”.

Table 2: Value streams for Flexibility Valuation Mechanisms

Value Stream	1.06 Section	Valuation	Reference Section in this report 1.07
Proposed Short Term Flexible Service Valuation	2.1	Traditional Reinforcement Net Present Value (NPV)	3.2 II. Construction Projects
	2.2	Network Losses	3.4 Determining the Cost of an Upgrade
	2.3	Flexibility Service Administration and Management Costs	3.1 X. Contract Information
Possible Future Flexible Service Valuation	3.1	Remaining Asset Life Value	3.D.IV. Remaining Value of Replaced Assets
	3.2	Asset Life Costs (NPV+)	Modeled as part of this project
	3.3	Net Avoided Outage Costs (Asset Health)	3.1 II. Probability of asset failure
	4.1	Loss of Export Capacity	3.4 II. Tracking Cost of Running the System
	4.2	Avoided Energy	3.4 II. Tracking Cost of Running the System
	4.3	Community Generation Credit	3.1 VIII. Societal Cost
	4.4	Net Avoided Greenhouse Gasses (GHG)	3.3 IX. CO2 Emissions
Alternative Value Stream Options	5.1	Operating Assets Beyond Capacity	3.1 V. Cost of rating violations

Contact us:



futurenetworks@sse.com
www.ssen.co.uk/Innovation
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