IDEA – A GIS-BASED MULTI CRITERIA DECISION PLATFORM TO EVALUATE DER INTEGRATION

Matthias STIFTER  
arsenal research – Austria  
matthias.stifter@arsenal.ac.at

Christoph Mayr  
arsenal research - Austria  
christoph.mayr@arsenal.ac.at

Helfried Brunner  
arsenal research - Austria  
helfried.brunner@arsenal.ac.at

ABSTRACT
This paper describes the specification and conceptual design of an open platform for evaluating, planning and analysing the integration of distributed energy resources into the distributed power system. The development and integration of the open platform modules and tools will be presented: the GIS network planning and the power system simulation, which provide the input for the decision support system.

INTRODUCTION
Motivation
Frequently the planning and selection of distributed energy resources (DER) sites is based solely on the economic availability of primary energy. Other essential factors such as power system infrastructure and the local demand structure are often secondary factors. Furthermore, methods lack for comprehensive evaluation of site-specific characteristics of DER installations. These methods should combine the predicted power generation with other technical, ecological and economical assessment criteria. A model and a multi criteria decision tool were developed and incorporated into a Geographical Information System (GIS)-based numerical power system simulation environment. This platform enables the integral planning of DER sites, using analytical methods of geo-informatics and putting special emphasis on renewable energy sources, taking into account generation potentials and future demand scenarios.

Benefits
Using open and existing standards help to increase the interoperability between existing applications and systems. Especially self-describing and service-orientated interfaces enable the communication and data exchange of different applications. As an example the GIS server uses the Web Map Service (WMS) for providing data for the client. The iDEA platform is planned to be available as free and open source software (FOSS) when released. One of the most important advantages of FOSS is that everyone can contribute and improve existing code as well as merge different software packages into new and less costly applications. FOSS avoids reinventing the wheel and, in turn, helps progress.

The key benefit for integrating GIS and power flow simulation is to link geographical information, like the location of the network assets, with the model of the electrical network. This will increase the workflow of network and site planners drastically because of the consistency of the data and the automatic exchange of the site specific properties with their impact on the power system. Although making electrical network and geographical data public available is controversial, it could make the interconnection assessment for planned distributed generation more transparent. This in fact is asked by the regulator for the benefit of investors, but could be misconstrued by the network operators as untrustworthy.

Related Work
In comparison to commercial and other proposed applications the platform described in this paper not only provides a dataset for wind potentials or solar irradiation but takes the specific parameters from different sources as an input for the decision support system.

GIS and Power System model
Network operators use GIS for their infrastructure and utilities management and network construction planning. As a part of the network information system, the geographical data of the network is associated with the database of the utility. An interface to enterprise resource planning (ERP) software may exist for the organization of the resources. Furthermore, network planners often need the GIS data for simulating future planned network assets. In most cases, these two systems are separated and operate independently. The only link is an identification or location reference in a database table. Recently, the major GIS software houses have been trying to interface power system simulation software. This interface allows only one common and consistent database.

Thus, a GIS-based power system information platform can provide:
- Geographical, topological and schematic representation.
- Graphical representation of simulation analysis results.
- Cable layout and detailed local area network plan.
- Search and query functions.
- Live information about the network status.

Next-Generation Power Information System: This paper proposes an architecture for a "Next-Generation Power Information System" with a strong focus on the integration
DEVELOPING THE PLATFORM

Architecture

The iDEA platform architecture core, or back-end, consists of the simulation, evaluation and optimization module interfacing with the GIS and power system database. Web based and desktop client front-ends make up the user interface. Special emphasis is laid on the modularity of the platform. A well documented, open 'developer kit' enables easy creation and modification of modules for the platform. Fig. 1 shows the conceptual architecture of the iDEA platform. Modules which are not prototyped yet are shown in grey.

Fig. 1: Conceptual Architecture of the iDEA Platform

Fig. 2 shows a simplified assembly of the interfaces and modules for exchanging data which are necessary for the decision system.

Geospatial Analysis

The GIS module enables the analysis of characteristics of the site under assessment. Different layers can be added and as a criterion defined for the decision process. This could be for instance the solar irradiation map, population density and their future developing tendencies. Geographical features and analysis results, like the length of the line or the terrain of the connection line, could be also taken into

of live grid monitoring and metering of data for example to detect fault location. Similarities to the platform proposed in this paper could be found in terms of facilitating GIS applications with monitoring data and implementing standards and standardized interfaces for data exchange. (CIM, IEC 61850, OpenGIS, etc.) [1]

GridConnection: This is an interactive online “Connection assessment report” tool. Users are capable of editing the connection route from the newly erected generator site to the existing network. The assessment results in a detailed interconnection report [2].

EDP Energy and GE Energy: This network planning system comprises of the Smallworld GIS application with an embedded network analysis engine [3].

EDP - Technical Information System (SIT): Integration of GIS (Smallworld GIS) and DPlan, connecting the business data and SCADA/DMS with a central repository for network data: SIT. [4]

OBJECTIVES

The system will provide the means of integrating geographical data, network and regulatory framework-related issues to plan and evaluate potential sites for distributed generation with a focus on renewable energy technologies. Based on geospatial methods and network simulation the site-specific 'values' of distributed generation will be evaluated.

- Provide an open platform for geospatial analysis and estimation of site-specific criteria (e.g. meteorological data, solar irradiation, population density) and ecological-related criteria (e.g. protected area)
- Planning, optimization and evaluation of generation technology for technological and economical efficiency.
- Numerical simulation of the network and DG interconnection related issues (e.g. interconnection costs, transmission losses, maximum generation)
- Use the platform for teaching and training of network operators, planners and students
- Operation and management of the distributed network (e.g. fault visualisation, breaker state).
- Provide standardized interfaces for real time data from monitoring and metering devices.
- Scalable system in terms of number of nodes and sections in distribution networks.
- Service-orientated interfaces are available for visualizing the GIS-based data (e.g. network), for reporting and other functions.
- Web-based access makes the platform operable from many clients and thus more accessible.
- A strong emphasis is put on open standards and open programming interfaces to foster development of modules and plugins from a worldwide community.
account for the evaluation process. Different GIS clients have been adapted and extended (e.g. OpenJump, uDIG). Fig. 3 shows the projected network section on top of a satellite image and a site location for evaluation.

**Numerical Simulation**

Results of the power system analysis have been specified as criteria. These are for example the voltage level influence together with the maximum generation capacity or reinforcement costs. Due to the site location selected by the GIS client, the nearest connection to the existing network is located and the impact on the network calculated by the simulation module. For the prototype implementation, the free and open source application PSAT – Power System Analysis Toolbox – [5] is interfaced with the GIS model of the network.

**Integration**

The iDEA platform takes the geographical and the electrical network model and assures the consistency of the two datasets (Fig. 4). For instance, the bus and line identification and names are checked or the correct connections of buses and lines are validated. Due to this mechanism, both models appear as virtually one dataset (and managed consistently in the database). This assures that a query on the geographic information from the simulation tool, for instance length of the lines, would deliver valid and consistent data. The interested reader can find more details in [6].

**Evaluation and Ranking**

A common multi-criteria decision method – the Analytical Hierarchy Process (AHP) [7] – was implemented in the evaluation of DER integration. A basic set of significant criteria is defined, and each stakeholder – depending on his interests and priorities – creates a distinct profile (the pairwise comparison matrix or priority matrix). The nature of the criterion could be not only of qualitative origin but also quantitative (e.g. capital costs per installed kWh). Together with the location-specific criteria these profiles lead to a ranking of different potential candidates of installation sites and configurations of DER (the decision alternatives). The ranking is a result of satisfying the most criteria for each stakeholder and site. Multiple DER technologies, configurations and locations can be compared based on this decision support method.

**Data**

Data accuracy and availability is crucial for the operation of the platform. The necessary data for the site evaluation process are: network data of the area under investigation, country or state specific information (e.g. feed-in tariffs) and the geographical and meteorological information for the primary energy source (solar irradiation, etc.).

**EXAMPLE SCENARIO**

To evaluate a specific DER project, the location is chosen on the map and is then edited and configured according to the desired characteristics of the DER (Fig. 5). After providing the required parameters and the stakeholders’ preference profiles, the site configuration can be evaluated and subsequently optimized in terms of location, type or other criteria.

![Fig. 5: Views during the Site selection process](image)

Table 1 lists some site and generation alternatives which are under investigation for setting up a plant:

<table>
<thead>
<tr>
<th>Site</th>
<th>Generation technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>River</td>
<td>Small Hydro</td>
</tr>
<tr>
<td>Mountain</td>
<td>Wind turbine</td>
</tr>
<tr>
<td>Hill</td>
<td>PV System</td>
</tr>
<tr>
<td>Urban</td>
<td>CHP (gas)</td>
</tr>
</tbody>
</table>

**Table 1: Site Scenarios**

Example subset of the defined criteria and the origin of the specific criteria value are defined in Table 2:

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Name</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>cA</td>
<td>Prim. Energy Potentials</td>
<td>GIS Data</td>
</tr>
<tr>
<td>cB</td>
<td>Demand</td>
<td>GIS Analysis</td>
</tr>
<tr>
<td>cC</td>
<td>Infrastructure</td>
<td>PS Simulation</td>
</tr>
<tr>
<td>cD</td>
<td>Investment costs</td>
<td>DB Table (REF)</td>
</tr>
<tr>
<td>cE</td>
<td>Emissions</td>
<td>DB Table (REF)</td>
</tr>
</tbody>
</table>

**Table 2: Criteria and their calculation module**
Fundamental scale for pair-wise comparisons is shown in Table 3:

<table>
<thead>
<tr>
<th>Intensity of Importance</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Equal importance</td>
</tr>
<tr>
<td>2</td>
<td>Moderate importance</td>
</tr>
<tr>
<td>3</td>
<td>Strong importance</td>
</tr>
<tr>
<td>4</td>
<td>Extreme importance</td>
</tr>
</tbody>
</table>

Table 3: Priority intensities

<table>
<thead>
<tr>
<th>cA</th>
<th>cB</th>
<th>cC</th>
<th>cD</th>
<th>cE</th>
<th>priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>0.3479</td>
</tr>
<tr>
<td>1/3</td>
<td>1</td>
<td>1/2</td>
<td>1</td>
<td>3</td>
<td>0.1710</td>
</tr>
<tr>
<td>1/2</td>
<td>2</td>
<td>1</td>
<td>1/3</td>
<td>1</td>
<td>0.1506</td>
</tr>
<tr>
<td>1/4</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>0.1785</td>
</tr>
<tr>
<td>1</td>
<td>1/3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.1520</td>
</tr>
</tbody>
</table>

Table 4: A resulting priority for an example stakeholder profile ‘optimum penetration’

In Table 4, row: cA, column: cB read as: 'primary energy potentials are of strong importance compared to demand'. The column 'priority' results from the weighted eigenvalue of the matrix (see AHP [7]).

The next step determines how much the specific criteria of the alternatives cover the priority profile of the stakeholders. Fig. 6 shows the congruence of the different stakeholder priorities with the criteria of the site 'River' (hydrogen plant). Stakeholder 'environmental concerns' has the highest share of priority fulfilment.

Fig. 7 shows the result of the evaluation for four stakeholders and of four different sites: River: a small hydro power plant Mountain: a wind turbine, Hill: PV System and Urban: a CHP. The heights of the bars are according to the share of the stakeholders' priority for every site. The site 'Urban' has the highest sum of share in this example.

SUMMARY

A comprehensive and integrated assessment of Distributed Energy Resources (DER) integration helps to optimize the network in terms of enhancing operation, generation capacity, total DER share, local power quality, losses and interconnection costs.

Optimal development of DER integration is necessary for plant operators, investors and fund providers. With this open and freely-accessible software an evaluation environment is created to meet the objectives of the new Austrian act on electricity in terms of transparency and non-discriminating access to the power network for DER. Furthermore, it is possible to include the market rules and incentives for renewable technologies with focus on the location-specific factors – a step towards an integrated decentralized generation development.

REFERENCES