Xyna.energy

Energy optimization of Telco networks by AI-based forecasts.

Deriving localized weather prediction.
Calculating green power production and demand.
Optimizing cost and carbon footprint.

by
GIP AG Research Institute
Hechtsheimer Str. 35-37
55131 Mainz, Germany

www.gip.com

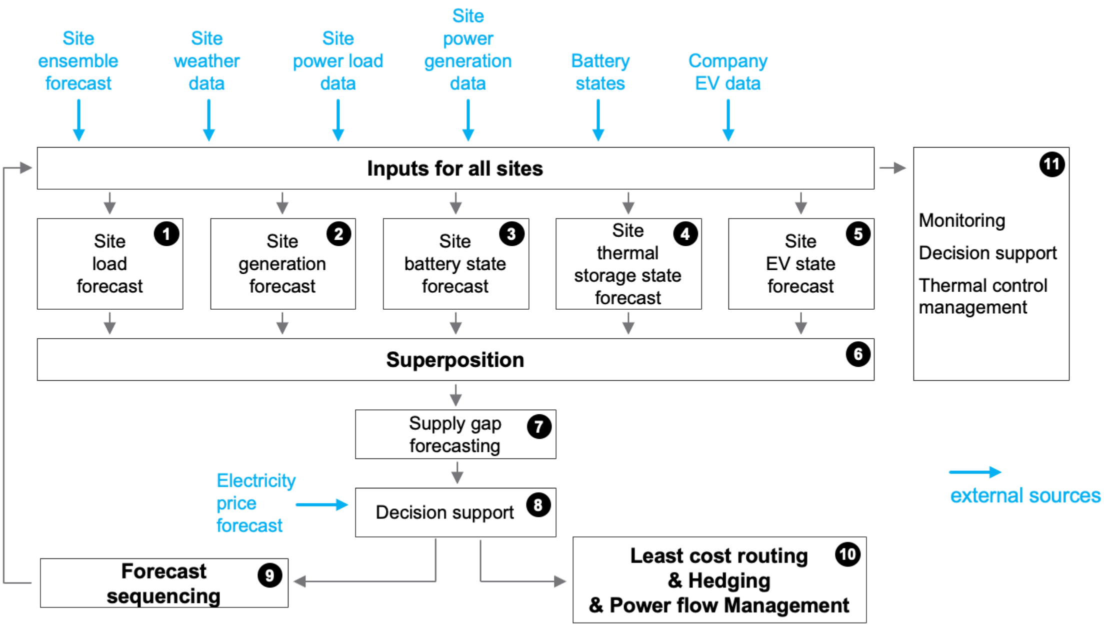
Content

1. Xyna.energy – Overview

Xyna.energy is a self-organized neuro-symbolic Xyna.ai system for optimized prosumer management through localized weather-dependent power generation, power demand, and volatility forecasts for price-optimized procurement and direct marketing feed-in using AI-based storage management.

The idea for Xyna.energy is based on the concepts of our patents for the Quantum Grid "A grid like the Internet". They describe how both the future electricity provided by renewable generation and the future volatile electricity demand are represented in the form of ensemble energy packages determined by AI-based forecasts, taking into account the volatility. The patents also include the procedure for self-organized AI-based matching generation and demand as well as storage management using a sequence of forecasts. AI-based resource routing of energy packets, as described in our latest patent, has influenced the AI-based power flow management.

Inspired by our latest patent, Xyna.energy consists of several interacting neuro-symbolic subsystems. These relate to self-organized processes and are autonomously controlled by a sequence of predictions, as shown in the figure below:



- The data inputs are: site ensemble forecast (FC), site meteorological forecasts (weather), site power load, site power generation, site energy storage states (batteries & thermal), load states of company EVs.
- These flow into a data lake / data warehouse and then become the site-related FC subsystems:

  ❶ Site load forecast
  ❷ Site generation forecast
  ❸ Site battery state forecast
  ❹ Site thermal storage state forecast
  ❺ Site EV state forecast

- Later in the process, the following subsystems are active:

- ❻ Superposition, combines the outputs of the models above
- ❼ Supply gap (shortfall or surplus) forecasting, calculates if the power supply is sufficient
- ❽ Decision support, incorporates electric price forecast
- ❾ Forecast sequencing:
  - If there is still an uncovered gap, the forecast is carried out and fed as an input into the process again.
  - If there is no more gap, the process is completed for the period under consideration. Periods that lie further in the future are triggered afterwards or in parallel.

- ❿ Combines multiple aspects
  - Least cost routing
  - Hedging
  - Power flow management

- ⓫ Combines several monitoring components
  - Thermal control management: to recognize, for example, whether the capacity for thermal control needs to be changed. This means increasing or reducing the size of fans or replacing them with thermoelectric devices or heat pumps for air cooling and/or heating or swap air cooling to liquid cooling.
  - Decision support

The subsystems create task-related forecasts, carry out optimizations, and provide the basis for decisions and control corresponding processes. These are described in the following text.

The symbolic part of Xyna.ai is used on the one hand to process tasks that can be solved more precisely using symbolic AI, but also as "guard rails" to avoid gross errors of the neural AI and then, for example, to trigger a human-in-the-loop process. Especially since transformers, in addition to GNN, GAT, CNN or other DLN types, can also be used for the various subtasks of the subsystems.

2. Objectives

The following goals should be pursued:

a. **Cost optimization**: in addition to green PPAs long-term and short-term (day-ahead and intraday) purchasing/selling, trades at the EEX in Leipzig, the EPEX in Paris (for Europe) and Nodal Exchange and other local marketplaces (in the US) can be optimized through better AI-based demand and generation prediction through better background data, e.g. AI-based ensemble weather forecasts.

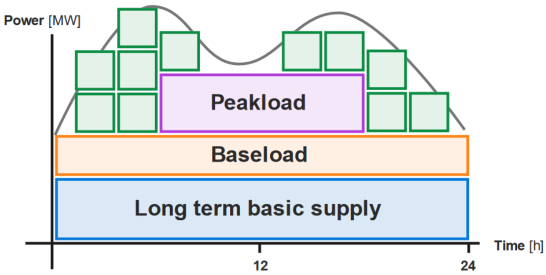
b. **Revenue optimization**: of revenues from own production and storage capacities to sell them, for example, as Frequency Containment Reserve (FCR / primary reserve), automatic Frequency Restoration Reserve (aFRR) and manual Frequency Restoration Reserve (mFRR) on the open market.

c. Minimization of costs for balancing energy.

d. Selling of self-produced electricity as FCR, aFRR, and mFRR control power.

3. Motivation

Due to the volatile load and green self-generation, the external electricity demand cannot be fully covered cost-effectively with Power Purchase Agreements (PPAs). For this reason, only the long-term basic supply as well as the base and peak load, i.e. the safely projected proportion of the demand, that is required in each case, is covered by PPAs.

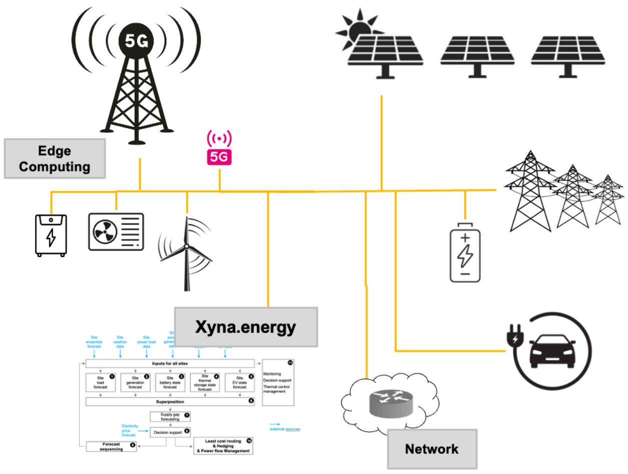


The gap between the PPA and the actual demand is filled by short-term, flexible transactions, taking advantage of attractive prices on the exchanges. Energy storage systems, such as batteries, are playing an increasingly important role in flexibility management. Load, green self-generation, and storage capacity forecasts are used to determine the gap. Price forecasts on the exchanges and trading platforms are also useful.

Not only is green self-generation dependent on the weather, but electricity demand is also influenced by the weather. As a result of climate change, we will experience increasingly large temperature differences. Summers will become hotter and, in the US for example, winters will become colder due to the shift in the jet stream and these phases will last longer.

Higher or lower temperatures immediately lead to a higher demand for electricity for cooling or heating, which is increasingly being provided electrically by heat pumps. The electrification of company vehicles is also influenced by the weather. At higher temperatures, more electricity is needed to keep the vehicles and their batteries at the right temperature. The situation is similar when it is colder than normal in winter. In general, weather-related power consumption depends on the location of the facility, such as outdoor network equipment, edge computing, data centers and offices, as well as the current locations of the electric vehicles.

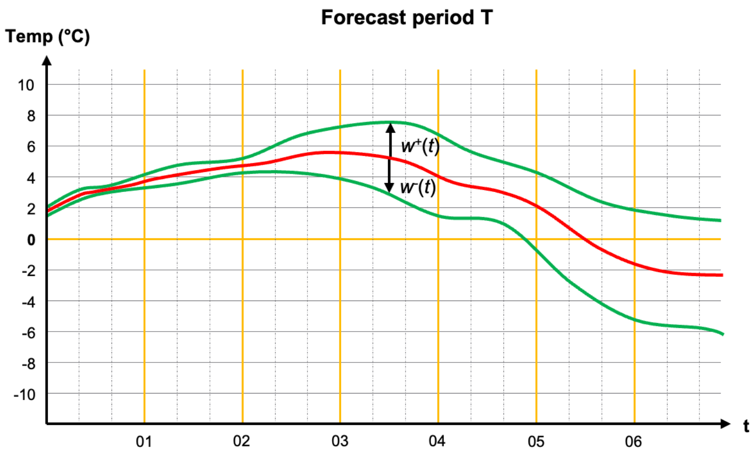
System environment



It is not only the daily variation in air temperature that plays a role here, but also direct sunlight and shading. This is because the power consumption for temperature control increases with the difference between the outside temperature and the set temperature. In addition, the temperature input due to the daily course of direct sunlight must also be considered. The weather forecast is therefore an important input for the above-mentioned forecasts and especially the electricity consumption for temperature control. In the following, whenever we refer to load forecasts, we mean the forecasts for the electricity requirements of temperature control.

However, the available weather forecasts only have a spatial resolution in the size of their forecast tiles. This spatial resolution alone can lead to deviations, e.g. between the predicted temperature of the tile and the actual temperature. In addition, the longer-term the weather forecasts are, the less reliable they are. Ensemble forecasts are used to overcome this variance.

Ensemble weather forecasts as a basis for local forecasts and volatility



- The weather forecasts with different realistic parameters (ensembles) result in different courses for the predicted parameters $x(t)$ in the forecast period T.
- An average value $w_{nom}(t)$ can be derived from this.
- The two $w_x(t)$ denote the upper and lower deviation from $w_{nom}(t)$.
- So the skew-symmetrical fluctuation range that is to be expected.

4. Local weather-dependent load and generation forecasts

Let us formalize that a little. In the following, we describe the function of the neuro-symbolic AI component (❶) for the site load forecasting. We consider a site with the coordinates x_{ijk} consisting of the usual planar coordinates and a reference altitude. A weather model determines forecast values $w^r(y_{ijk}, t_0, T)$ at a forecast time t_0 for a forecast period. Where y_{ijk} are the vertices of the 3-dimensional model grid. These vertices form cubes by their edges.

From the ensemble weather forecasts the nominal value $w^r_{nom}(y_{ijk}, t_0, T)$ and the variations $w^r_+(y_{ijk}, t_0, T)$ *and* $w^r_-(y_{ijk}, t_0, T)$ can be derived. Where y_{ijk} are the vertices of the cube containing $x_{ijk.}$ The inputs of the neuro-symbolic AI system (❶) are $w^r_{nom}(y_{ijk}, t_0, T)$, $w^r_+(y_{ijk}, t_0, T)$, and $w^r_-(y_{ijk}, t_0, T)$ as well as the measured values at site x_{ijk}, such as outdoor temperature and power consumption of the temperature control system at time t_0. For the sake of simplicity, we will denote x_{ijk} with x.

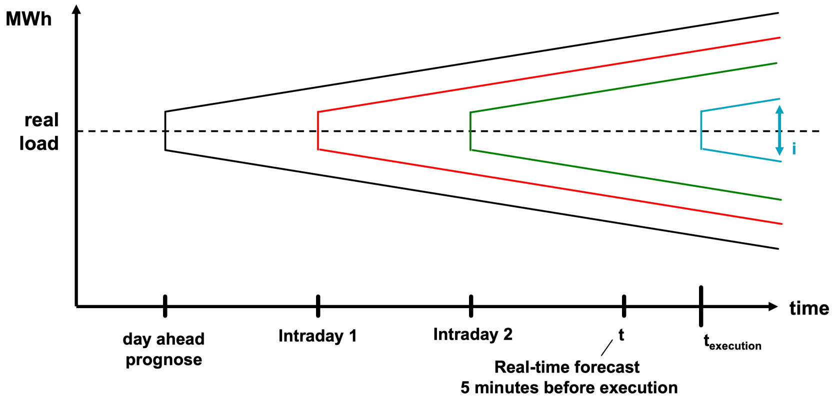
In each case at t_0, the nominal load curve $p_{nom}(x, t)$ for the temperature control system and the deviations $p^+(x, t)$ and $p^-(x, t)$ from $p_{nom}(x, t)$ (where $|p^+(x, t)| = |p^-(x, t)|$ is not required) for T are forecast as output. In other words, the AI is designed in such a way that a "quantized" ensemble load energy package $\tilde{L}(x,T) \cong \{L_{nom}(x,T), L^+(x,T), L^-(x,T)\}$ composed of elementary energy packages with a nominal package $L_{nom}(x, T)$ and the associated compensation or balancing packages $L^+(x, T)$ and $L^-(x, T)$ is determined for the period T. For more details see chapter 7.

$L^+(x, T)$ and $L^-(x, T)$ are the volatility forecast. In the event that $L_{nom}(x, T)$ is provided by supply contracts, own generation or from batteries, $L^+(x, T)$ describes the possible shortfall and $L^-(x, T)$ the possible surplus.

Similarly, a "quantized" ensemble energy generation package $\tilde{G}(x,T) \cong \{G_{nom}(x,T), \mathrm{G}^+(x,T), \mathrm{G}^-(x,T)\}$ composed of $G_{nom}(x, T)$, $G^+(x, T)$, and $G^-(x, T)$ is determined for each regenerative generator system at site x form the site generation forecast system (❷). The load and generation ensemble packages are superpositioned in (❻) to determine the total demand. The calculation rules of our patent (appendix A, 1) apply. The quantized PPA packets (appendix A, 2) are subtracted from the resulting ensemble packet to determine in (❼) the quantized ensemble gap packet.

The corresponding ensemble packets are determined in a converging sequence of forecast time points, with ever shorter intervals to the execution time, at least 5 minutes before execution as the last forecast. This happens in (❾)

Simplified representation of the converting forecast order



Expansion level 1: more sophisticated status forecasts

As a potential extension, the AI system will be expanded to include a component (❸) for more precise local weather-dependent battery storage status forecasts, as well as forecasts (❹) of thermal storage potential resulting from the permissible temperature elasticity of the location.

This forecasts the capacity that the battery can deliver or absorb in terms of energy or power at the time of the forecast in the forecast period under consideration.

The following points are realized in the expansion stages:

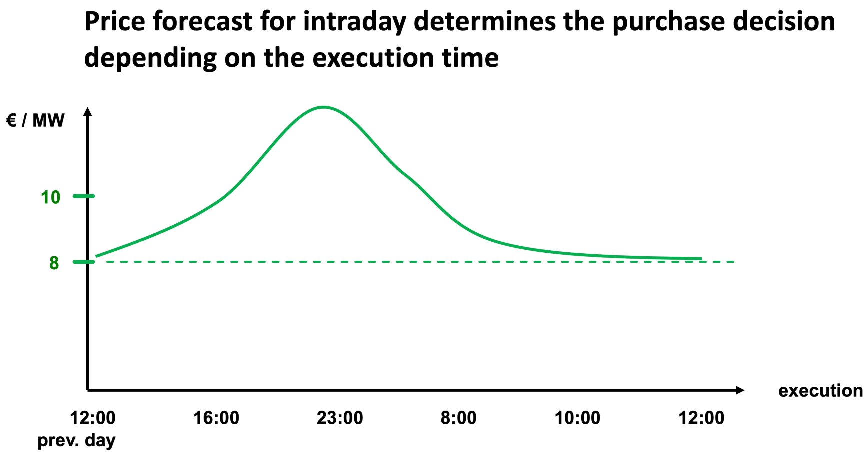
1. Electric company vehicles: in the following step, a corresponding component (❺) of the AI system is designed and the AIs are trained for each type of company vehicle used on the basis of corresponding time series, which, analogous to the previous points, **forecasts on the basis of the weather-dependent battery status**, as well as the weather-dependent discharge losses of the battery and the forecast of the losses when charging the battery.

2. **Weather-dependent consumption forecasts** depending on the route for planned business trips by service personnel.

3. Derivation of a charging plan (time and location) depending on the **consumption forecasts** and the battery status forecasts, such as the available capacity and the actions on the exchanges.

4. **AI-supported purchase and sale forecasts** based on the cumulative local load and generation forecasts, the forecast of the cumulative capacity available in storage facilities and the price forecasts on the exchanges to buy or sell the difference that is under- or over-covered by the PPA.

To be able to select favorable times for actions on the exchange such as buying/selling or waiting for rising/falling prices, forecasts of the price development are created by the decision support component of the AI system to support decision-making. For the day-ahead and intraday forecasts, ensemble weather forecasts are carried out for the locations of the most important certified green electricity suppliers.



5. Expansion level 1: Energy market buy/sell recommendations

Based on these stock market price forecasts and the ensemble gap packages, the Decision support component (❾) can make recommendations for action. Which is the input for the neuro-symbolic-AI component (❿) for purchase, hedging and power flow control.

Another task of (❽) and (❿) is to support the marketing of the provision of control power capacity for Frequency Containment Reserve (FCR), also known as Primary Control Reserve (PCR), automatic Frequency Restoration Reserve (aFRR), and manual Frequency Restoration Reserve (mFRR). This can be made available by forecasting capacities of storage and V2G (Vehicle to Grid) capacities which are not allocated. In addition, the potential for load shedding is also determined and can be made available as part of demand-side management. Particularly interesting for the US. With the expansion of the previous methodology, the corresponding capacities can then be determined.

6. Expansion level 2: Telco Virtual Smart Grid

In the final development stage, a virtual smart grid spanning a Telco's sites can be realized based on one of our patents (see appendix A, 3). This enables the control and regulation of the power flow for the feed-in from the company's own green generation and storage and the coherent withdrawal from the company's own sources and from the grid for the PPAs. In addition, our patent for power distribution (see appendix A, 2) offers the possibility of forming a swarm storage system from the distributed storage system, which behaves like a storage system. Since the US do not have an electricity transmission system that spans the entire country, such a virtual smart grid spanning also US locations can also be realized for the US through corresponding contractually guaranteed transmission capacities between the individual US grids.

- Xyna.energy is to be realized with the xyna.ai technology that is currently being developed. In doing so, Xyna.energy is to become a hierarchical system consisting of neuro-symbolic AI subsystems for the respective task. Emphasis is placed on the design as an AI with minimized power consumption. Thus, one embodiment can be that the tasks of expansion stage 1 are realized locally at the site using small computers such as the Raspberry pi 5 and a federated & coherent connection, according to our patent (see appendix A, 4), to cost-effective cloud computing capacities utilizing spare resources.

- Necessary process automation, e.g. for interaction with third-party systems, is implemented with xyna.com/Xyna Factory. Xyna Factory is an automation platform for technical workflows.

7. Background: the “Quantum Grid” approach

The R&D work on Xyna.energy is backed-up by our own patents (see appendix A, references 1, 2 and 3). In these writings, the basic idea of designing and building a power grid analogous to the Internet is outlined and developed.

The essential aspects briefly summarized:

- "**Quantization**" of the energy transmitted by the current in a time period *T* by mapping this energy by means of the superposition of elementary energy packets *dE* with *n*dt=T*. The following applies: *dE=dp*dt*, where *dp* is an elementary power that is constant over *dt*.

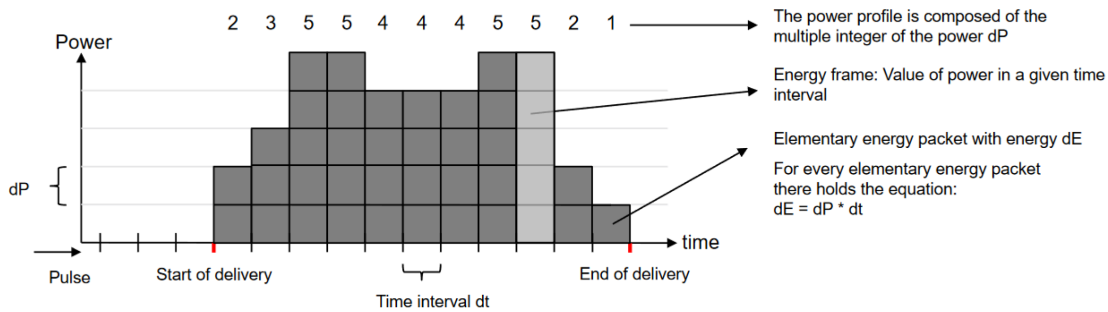


Fig. 3 Power profile: Quantization of power and time that gives rise to the energy packet

- This quantization simplifies the effort for xyna.ai, as only integers must be processed. In addition, packages that can be represented as integer multiples of an elementary package are traded on the exchanges.
- For the respective forecast and forecasting time, forecasting period *T* determination of regenerative energy packages (see appendix A, 1) by means of AI using ensemble weather forecasts and measurement data from the generation plants, according to appendix A (1), an equivalence class [$p_{nom}(x, t)$, *R(t), T*] where *R(t)* is a function of $p^+(x, t)$ and $p^-(x, t)$) is determined.
- To apply our corresponding patents (see appendix A) to this context, the ensemble package is defined here afterwards:
- An ensemble energy package $\tilde{E}(x,T)$ can then be derived from this equivalence class with $\tilde{E}(x,T) \cong \{E_{nom}(x,T),\ E^+(x,T), E^-(x,T)\}$ with x being the location of the generation or load side. With a nominal energy package E_{nom} and the balancing energy packages E^+ and E^-.
- We distinguish between the ensemble energy packets for generation, which we denote by $\tilde{G}(x, T)$, and the ensemble energy packets for load, which we denote by $\tilde{L}$ (x, T). Accordingly, $\tilde{G}(x, T)$ is assigned the tuple $\{G_{nom}(x, T), G^+(x, T), G^-(x, T)\}$ and $\tilde{L}(x, T)$ the tuple $\{L_{nom}(x, T), L^+(x, T), L^-(x, T)\}$.
- Load forecasts for the individual EVs based on local measured load values, weather-dependent load profiles, user-dependent load profiles such as known business trips with EVs.
- AI-based storage management for the provision of E^+ or the absorption of E^-, as well as the provision of FCR, aFRR, and mFRR control power.

The development of Xyna.energy is to be developed in several expansion stages, each with an expanded range of functions.

Appendix A: Patent references

The following patents form the theoretical background.

(1) EP 4 012 871 B1
METHOD FOR THE DIRECTED TRANSMISSION OF ENERGY IN THE FORM OF ENERGY PACKETS
Dr. Bernd Reifenhäuser, 08.12.2020

(2) US 10361564 B2
ELECTRONICAL POWER DISTRIBUTION AND METHOD FOR DISTRIBUTING ELECTRICAL POWER
Dr. Bernd Reifenhäuser, Dr. Alexander Ebbes, 24.11.2016

(3) EP 2 430 723 B1 (Europe)
US 9337655 B2 (USA)
METHOD AND APPARATUS FOR THE DIRECTIONAL TRANSMISSION OF ELECTRICITY IN AN ELECTRICITY GRID
Dr. Bernd Reifenhäuser, Dr. Alexander Ebbes, 05.05.2010

(4) EP 2 250 588 B1 (Europe)
US 8.296.368 B2 (USA)
METHOD AND PROGRAM FOR PROVIDING DATA COHERENCE IN NETWORKS
Dr. Bernd Reifenhäuser, Dr. Alexander Ebbes, 27.02.2009

The idea of the Quantum Grid has already been published in many articles, publications, and presentations at conferences.

For further information see the GIP AG website: https://www.gip.com/future-energy

See in particular the Quantum Grid white paper at:

https://www.gip.com/media/gip_whitepaper_qgb_en_180220.pdf

Appendix B: Company structure & people

- **GIP AG** Research Institute**:** the nucleus for innovation, intellectual property, patents and incubator for research and development with a strong focus on AI.

  The portfolio for innovative approaches goes from Future Energy to Future Networks & Smart Infrastructure to Future Biology, e.g. the application of GenAI on synthetic / generative Biology.

  From a financial point of view, GIP AG is a holding company for the GIP Group companies.

- **GIP Exyr GmbH:** system integration, consultancy, and software development (> 50 employees) with a focus on network-centric process and service automation. Specializing in sensitive systems in critical infrastructures.

- **Xyna GmbH:** our 2023 startup for intelligent AI-based solutions with a focus on automating and integrating AI into existing distributed system and complex process landscapes. Currently concentrated on GenAI for process automation / code generation and neuro-symbolic approaches based on open models for reliable, transparent, and independent solutions in the context of critical infrastructures.

  All specific development work is carried out by GIP Exyr GmbH and Xyna GmbH.

Behind all ideas and developments is our great team of people with a wide scope of professions and academic backgrounds.

Xyna.energy was essentially driven by:

- **Dr. Bernd Reifenhäuser**
  Physicists, entrepreneur, inventor, and "hacker of the power grid"

  https://www.linkedin.com/in/dr-bernd-reifenhäuser-107281214/

  His passion for meeting the challenges of our increasingly complex and interconnected world with innovative ideas motivates us every day and drives the development of exciting approaches.

- **Dr. Alexander Ebbes**
  Physicist, inventor, technical mastermind, and leader of the operational teams

  https://www.linkedin.com/in/alexanderebbes/

  His enthusiasm for artificial intelligence in its various waves has accompanied him since the beginning of his career. With Xyna.AI, founded in 2023, he implements intelligent and innovative approaches to the application of AI in demanding tasks.

Appendix C: References / GIP Exyr GmbH

We have a long-standing business partnership with Deutsche Telekom, Vodafone, and other tier-1 carriers, which over time has resulted in a series of OSS/IT systems for network configuration based on our automation platform Xyna Factory.

Among other projects, we are active in the following areas (more detailed details available upon request, NDAs apply):

- Highly automated enterprise access services (L2/L3) including DHCP and zero-touch activation.
- 360° SD-WAN platform for large chain store VPNs including order management and roll-out tools.
- Provisioning with resource management + network abstraction + activation for individual market (including wholesale, Ethernet, IP-VPN), company networks (including mobile backhaul), and carrier solutions (including IPX, IP-Transit, cloud-based DDoS-Defense).

www.xyna.com