First Project Experience and Case Study about our Hybrid Controller for Energy Systems in Africa

Maren Gast
Product and Solution Management Phoenix Contact Electronics GmbH in Bad Pyrmont, Germany
mgast@phoenixcontact.com

Abstract — **Over the past 2 years we have continuously developed our controller for hybrid energy systems based on an open control technology. In 2020 we realized a couple of projects together with the EPC Soventix GmbH [1]. Most of the projects are in Nigeria. This paper will give an overview about one of the projects, the requirements to the hybrid controller and the possibilities to reduce the amount of fossil energies with the help of installation of photovoltaic systems. Furthermore, you get insides in our load management system which can easy adapted to customer specific requirements with the help of an open control technology together with model-based design.**

load management, model-based design, hybrid energy systems, hybrid controller, fuel reduction

I. ACTIS´ JABI LAKE MALL

The hybrid system of the shopping center Jabi Lake Mall (Figure 1) in Abuja, Nigeria consists of a 609 kWp PV rooftop system, 8 Huawei 2000 60 KTL converters and 3 F.G. Wilson heavy oil generators (Figure 2) with a rated output power of 1600 kW and reduces CO2 emissions and electricity costs significantly. With the help of this PV system, it is possible to drastically reduce the heavy oil consumption of the 3 gensets.

Figure 1. Aerial view of the Jabi Lake Mall

Figure 2. F.G. Wilson heavy oil generators

Our hybrid controller monitors the upper and lower power thresholds of the generators and ensures that the inverters of the PV system can regulated down in the event of an impending underload.

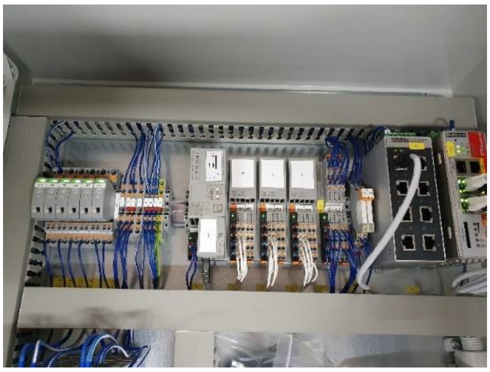

Figure 3. Installed load controller based on PLCnext technology

The Single line diagram shows 4 loads (Figure 4). The Jabi Lake Mall is divided into the 4 different load areas MSB 1. 1, MSB 1.2, MSB 2.1 and MSB 2.2.

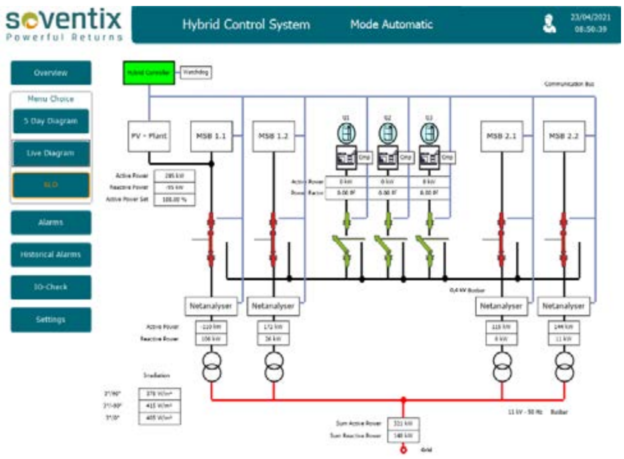

Figure 4. Screen of the visualization – Single line diagram

The energy demand of these areas is measured by energy meters here also named netanalyzer. The Jabi Lake Mall is connected to the local power grid, but it is not allowed to feed the power of the PV plant into the grid. If the active power demands of the loads are lower than the current active power production of the PV power plant the inverters must be regulated down. This task is also done by the hybrid controller.

If the local power grid is not available, the heavy oil generators starts, the green switches are closed to supply the 4 load areas. At the same time the red switches are open.

Before the power threshold of 30 % of the nominal power of the generators is undercut, the hybrid controller must regulate the inverters of the PV system down. This is necessary, to ensure that the generators always run in the optimum operating range and do not coke up.

The inverters of the PV system can provide not only active power but also reactive power if required. Many inductive and capacitive power losses occur in the system caused by the transformers and cabling. For these power losses, reactive power would have to be drawn from the grid. To further reduce operating costs, the provision of this reactive power can be controlled by the hybrid controller.

The visualization screen (figure 5) shows the current power distribution overview of Jabi Lake Mall at the 23rd of April at 8.58 am. At this moment the energy demand is low because the shopping mall is still closed. You can also see the energy data of the day, month and year. In the first 4 month of the year 2021 73,8% of the energy was covered by the grid, 10,6% by the diesel Generator and 15,6 % by the PV system. The amount of the photovoltaic power is expected to increase further during the summer month.

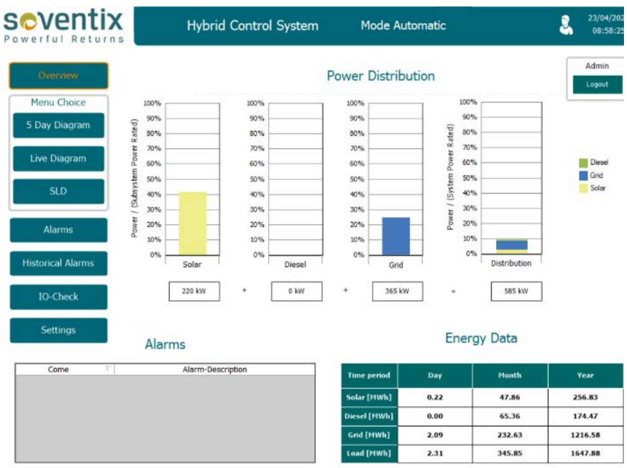

Figure 5. Screen of the visualization – Power distrubution

This solar hybrid project is the first of its art for a Nigerian mall. Cross Boundary Energy (CBE) [2] financed the 600kW rooftop solar plant and sell power to Jabi Lake Mall through an innovative 15-year power purchase agreement. The power offers a cheaper energy alternative and will reduce the shopping center's CO2 emissions by over 13,000 tons per year. CBE received the AFSIA Africa's C&I Solar Project of the year award.

II. General Concept of a hybrid Controller

With the hybrid controller, a modular control system from Phoenix Contact, all components in the hybrid energy system run at the ideal operating point (figure 6). The hybrid controller monitors and controls the necessary loads of the consumers, the PV power, the generator power and the real-time charging state of the batteries. Depending on requirements, feed-in control into a utility grid can also be realized. The hybrid controller via our PLCnext Engineer software or suitable simulation interfaces. This features globally uniform operation, thanks to programming in accordance with the international IEC 61131 standards or high-level languages, as well as a programming environment for all Phoenix Contact controllers. Many application-related function blocks are available. These enable fast and simple access to components, for example inverters and storage systems of different manufacturers, via various interfaces such as RS485, CAN or Ethernet, for example. The communication system for automating the hybrid energy system can be set up via numerous protocols, such as Modbus/RTU, Modbus/TCP and Sunspec. The load control is realized via a customer-specific application program. This can be created by the customer or commissioned as a service. The hybrid controller is connected to the individual units of the hybrid energy system via data interfaces. Additionally, measurement points are available at the grid feed-in point and The heart of the load management system is a PLCnext controller with analog and digital inputs and outputs, and the respective application program. The sink and source loads are measured via a current transformer and transmitted to a power measurement terminal. The various sources and sinks to realize an energy management using the measured data.

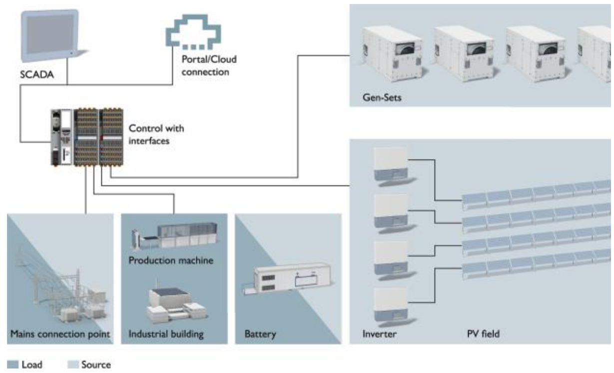

Figure 6. Topology of the load management for hybrid energy systems

A. Grid connection

Depending on the system location, a local power grid is available. In the case of unstable grids, the system must be able to run in stand-alone mode. In the case of a recurring grid, this must be synchronized with. The statuses of the switching elements can be recorded at the grid connection point. An EM-PRO grid analysis device with Modbus/TCP connection can be used for this. Synchronization with the grid is performed via the gensets (various generator types like diesel- or gas-generators), which are equipped with a connector for grid transducers as standard.

B. *Feed-in control*

Depending on the locally applicable legislature, a feed-in tariff for the electricity fed into the grid by the renewable energy system is available. Preprogrammed function blocks are available in Solarworx for feed-in control. The feed-in control function is activated via an SD memory card and taken on by the load controller.

C. *Load control and distribution*

If the load progression is known, the hybrid controller can be developed based on models. The gensets follow the load profile and are specifically switched depending on the load requirement. As the load increases, the gensets are connected successively, and are disconnected successively as the load sinks. This ensures that the genset park consumption is optimized. It must be ensured that power reserves are available to cover load jumps. The gensets are connected and disconnected by the hybrid controller according to their performance data. This ensures that the operating hours of the individual gensets are evenly distributed. The active gensets must distribute the load. This load distribution is also realized via the load management system. With this approach, one genset can be specified to produce a certain amount of power, and the remaining gensets generate the energy deficit.

D. *PV system*

The string inverters in the PV system can be connected to the hybrid controller via a communication interface. The data logger functions, such as connection to an operational management portal and communication interface for the subordinated inverters, can be realized by the hybrid controller.

E. *Battery storage*

It is expedient to integrate storage systems to compensate fluctuations in the power grid and to cover peak loads. The genset operation can be optimized via the targeted regulation of the storage system. As a rule, the hybrid controller system communicates with the battery management system.

F. *Portal connection and visualization*

The hybrid controller system for energy systems can make data available to superordinate systems via its Ethernet port. Communication blocks are already available for some PV portals. The hybrid controller system also has a configurable homepage available as standard, in which configuration data, real-time data and operating levels can be displayed. This can, for example, be used by maintenance personnel for configuring the hybrid controller. The homepage can be used for simple visualization tasks. Access is via Ethernet and a device with a standard web browser. Smartphones, tablets, etc. could be used for this should the system be equipped with WLAN.

The controller data can be transmitted via an interface (Modbus/TCP, OPC) to a SCADA system. This SCADA system is optimized for the dynamic presentation of values. Libraries with turnkey visualization objects are available. Furthermore, customer-specific, or system-specific Visualization objects can be freely created. Along with the ability to display runtime values, the system is also capable of displaying historical data. Alert management with time stamp is also possible. This SCADA software runs on a PC, which exchanges data with the Load Management system via an Ethernet connection.

III. Model Based design

Shorter product development schedules, better performing products, reduced development budgets and accelerated product customization are the driving factors for companies to use model-based design. For the development of the hybrid controller for energy systems is MATLAB/ Simulink®, a software of the company MathWorks for model-based description of continuous and discrete systems, used (figure 7).

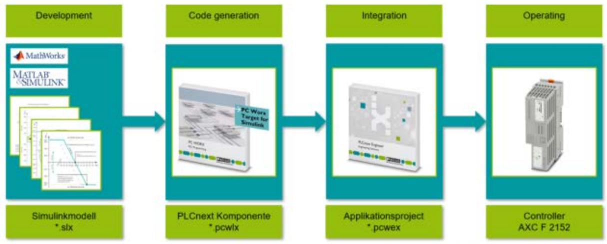

Figure 7. Engineering process with MATLAB/Simulink®

The more accurate the model, the better the load management works. The "PLCnext Target for Simulink" simulation environment creates device-specific files for the target language compiler and includes an HLLI firmware library which can be integrated into PLCnext Engineer and executed as an application project in the controller. Our PLCnext Target for Simulink allows automatic conversion of MATLAB/Simulink® models into device-specific code for the controller being used. The advantages of our PLCnext Target are structured program implementation and simulation/verification in advance, thanks to model-based system design. With the early-stage system simulation and startup by means of “hardware in the loop” as well as quick and easy system testing by means of “Rapid Prototyping” you are well supported.

IV. Conclusion

Our hybrid controller for energy systems is modular and extendable and can be tailored to each customer-specific application. Thanks to the open control platform, all inverter, battery storage system, and genset types can be integrated. The hybrid energy system can be extended as necessary at any time.

References

[1] Soventix GmbH, Am Schornacker 121, D-46485 Wesel: As an international development and engineering company, Soventix offers a broad spectrum of planning and consulting services for solar projects throughout all stages.

[2] Crossboundary Energy, Africa, energy@crossboundary.com: CBE unlocks capital to provide cleaner and cheaper power to enterproses in Africa.