

Load Management for Hybrid Energy Systems

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Abstract— Hybrid energy system operators and system integrators face the challenge of combining a wide range of different PV inverters, electricity storage systems and other electricity sources and sinks into one system. The energy flows of the sources and sinks must be monitored and controlled. Electricity storage systems and diesel generators must be operated at the ideal operating point in order to realize a long system lifetime. Where necessary, the PV system must be regulated and the electricity utility grid stabilized. Operating a hybrid energy system is complex, and each system is individual.

load management, model-based design, hybrid energy systems

I. INTRODUCTION

With the Load Management, a modular control system from Phoenix Contact, all components in the hybrid energy system run at the ideal operating point. The Load Management system 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 Load Management system is programmed via our PCWorx software (Software package for PC-based automation solutions contains all 5 IEC languages) or suitable simulation interfaces. This features globally uniform operation, thanks to programming in accordance with the international IEC 61131 standards, as well as a programming environment for all Phoenix Contact controllers. A large number of application-related function blocks are available in the Solarworx library (software library for PCWorx specifically developed for the implementation of photovoltaics projects). 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 Load Management system 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 various sources and sinks in order to realize an energy management using the measured data.

II. SYSTEM OVERVIEW

At this point, as an example, a potential version for automating a hybrid energy system will be presented in figure 1.

The heart of the Load Management system is a 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.

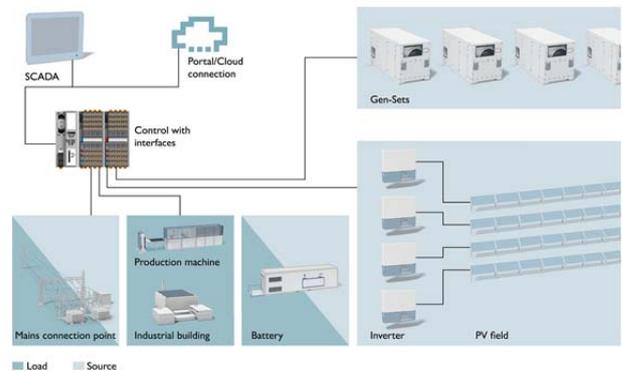


Figure 1. Topology of the load management for hybrid energy systems

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 Load Management system 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 load controller according to their performance data. This ensures that the operating hours of the individual gensets are evenly distributed. The active gensets have to 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 Load Management system via a communication interface. A large number of function blocks are available for this in Solarworx. The data logger functions, such as connection to an operational management portal and communication interface for the subordinated inverters, can be realized by the Load Management system.

E. Battery storage

It is expedient to integrate storage systems in order 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 Load Management system communicates with the battery management system.

F. Portal connection and visualization

The Load Management system for hybrid energy systems can make data available to superordinate systems via its Ethernet port. Communication blocks are already available for some PV portals. The Load Management 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 Load Management system. 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 Load Management for hybrid energy systems is MATLAB/Simulink®, a software of the company MathWorks for model-based description of continuous and discrete systems, used [1]. The sooner a fault is detected during the project development phase, the more costs can be saved [2]. This also applies to the development of hybrid energy systems. The ratio of the relative costs to the project phase is illustrated in figure 2.

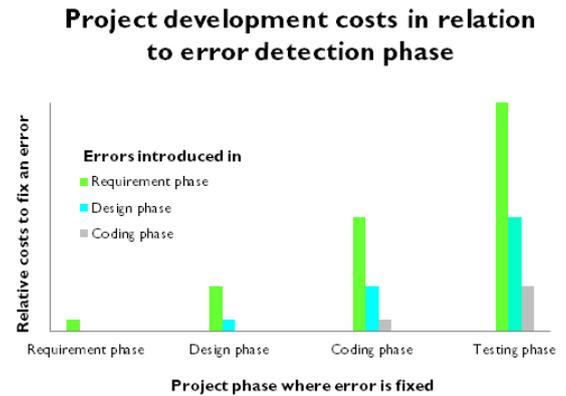


Figure 2. Cost reduction thanks to model based design

A. Modeling of the whole system

MATLAB/Simulink® ensures the simulation of the whole hybrid energy system. Each parts of the systems using MATLAB/Simulink®, and tested in the simulation environment. In the following the single steps of the model based design are explained:

- a) *Modeling of the whole hybrid energy system in MATLAB/ Simulink®*
- b) *Simulation in the development environment*
- c) *Test of the system in the real time development environment*
- d) *Code generation from model to machine code*

The more accurate the model, the better the load management works. The "PC WORX 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 PCWorx and executed as an application project in the controller. Our PC WORX Target for Simulink allows automatic conversion of MATLAB/Simulink® models into device-specific code for the controller being used. The advantages of our PC WORX 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.

I. CONCLUSION

Our Load Management system for hybrid 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] Wolf Dieter Pietruszka, “MATLAB und Simulink in der Ingenieurspraxis”, Springer Vieweg, September 2014.
- [2] System Design: New Product Development for Mechatronics, January 2008, Aberdeen Group