The Use an Electric Vehicle as a Power Source

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Abstract: Electric cars are becoming a serious competition for the common artificial fuel driven cars in small city agglomerates and short distances. With the new developments on the field of state-of-art accumulators, electric cars are becoming much more that just a single use items, but can serve a number of roles. One of them is possibility to use excessive energy stored in the batteries and its rerouting from the car to other systems (such as offices, family houses, lighting etc.). This brief article is making a suggestion on usage and lifecycle of traction batteries, interconnection of the house and its electric car. Additionally, logic and control of such a transfer processes is put to the test for conclusion, that the electric car can be used as both the mean of transportation as well as energy source while in the meantime its primary function is not dampened at all.

1 INTRODUCTION

Due to increasing number of cases where local energy sources are disrupted by climatic changes or by due to human interventions, there is ever increasing need for independent energy and heat sources. Also related to those, there is a high demand for "clean energy sources" and small energy producing units that are capable of sustaining local establishments, such as family houses etc. Hand in hand with these demands, there is also a pressing need to properly store unused energy for later usage by the residents or users.

1.1 Electric Energy

Electrical energy for charging electric vehicles can be removed from the public grid or the local (domestic) alternative and renewable sources.

The most common alternative and renewable sources of electricity are photovoltaic systems. The cost of acquisition is continually reduced and impact on the environment in terms pollution CO_2 is minimal in the active part of their lives.

1.1.1 Design PV Plant

During the design of the PV plant we need to establish basic facts as a surface roof, orientation, angle of the panelling, type panels and their efficiency and power. The design monocrystalic PV plant is on the roof library, Technical University of Ostrava (49.8314019N, 18.1622161E).

We need to use the surface of the roof (96m^2), orientation (south) and angle of the panelling (35°). In case of installation of the panels with power of 120 Wp we will need 160 pcs. of them and installed power will be 20 kWp. Interactive Maps, 2015.

As it is obvious from the previous data, photovoltaic systems are producing energy during times we cannot utilize it directly and would be wasted (9 AM to 6 PM). Therefore we need technologies that would store this energy with minimal losses.

For accumulation of gained energy, we can use:

- Electrochemical batteries;
- Capacitors and supercapacitors;
- Byproduct (ex. heat, cold, hydrogen, etc.);
- Mechanical and hydraulic accumulators.

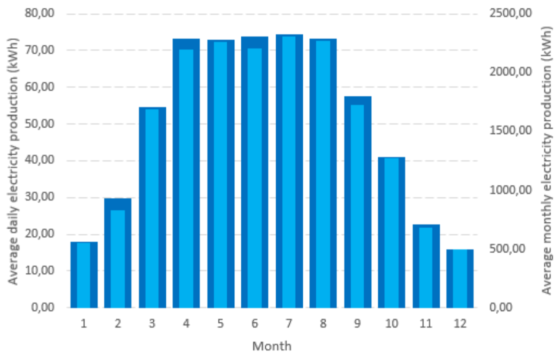

Figure 1: Average electricity production PV plant. Interactive Maps, 2015.

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1.1.2 Family House Energy Consumption

Energy consumption of family house is dependent on many different home appliances, but due to better access to state of the art products, consumption can be better distributed and lowered (side demand management).

Days when most consumption was created by heating and water management are over, almost 50% of the current consumption is created by home appliances that are becoming more and more common in most homes. Some of them, like a fridge, needs to be turned on and connected 24/7, others can be connected when needed (oven, microwave and others). Haluza, M., TZB info, 2012.

Figure 2: Graphical balance of the consumption.

As it was said before, some appliances needs to be plugged in all the time (fridge, freezer, alarm etc.), while others are used only when needed or allowed by the user or the technology (side demand management).

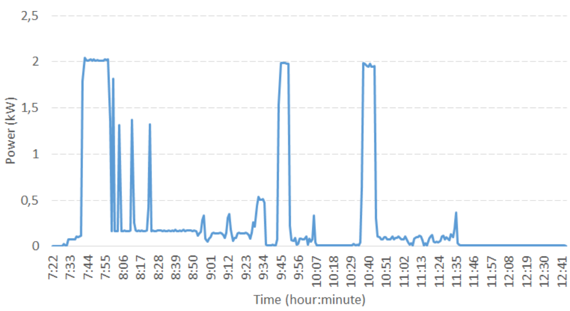

Figure 3: The consumption appliances - washing machine.

Due to connect households to a three-phase network, the individual phases are measured separately so we can decipher the individual electric circuits. Together with the schedule of individual daily tasks that depend on electricity (appliances), can be decipher consumption relatively detailed. Channel 1 measured - kitchen appliances and lighting equipment, channel 2 - heating, channel 3 - hot water. Friedrischkova, K.,Workshop, 2014.

Customs and behavior of the members of particular household differs during workdays (most consumption happens during 2 PM to 8PM) and

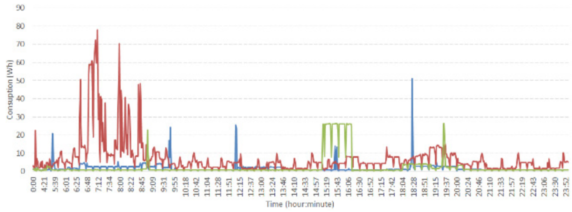

Figure 4: Consumption in house with 4 family members.

Customs and behavior of the members of particular household differs during workdays (most consumption happens during 2 PM to 8PM) and weekends (most consumption happens during 7 AM to 12 AM). Friedrischkova, K.,Workshop, 2014

The weekly consumption in house with 4 family members is average 25kWh.

1.1.3 Electric Vehicle

In connection with this main idea, research and development was conducted during the period of 2009 - 2012, involving commercial co-investigators, on electric drive unit. This project included four prototypes of vehicles (K0-electric vehicle for suburban traffic, K1- electric vehicle for long range, K2 - electric vehicle with Range Extender to extend the range, K3 - hybrid vehicle, into which it is possible to build in various types of sources (batteries, range extender for LPG, CNG, petrol, diesel or hydrogen)). Horak, B., Proceedings of the 14th International Scientific Conference Electric Power Engineering 2013.

The implemented experiments then demonstrated that vehicles consume an average of 10kWh/100km.

Elaborated study on transport services in Ostrava showed that the average vehicles daily driving distance is up to 50km. The remaining energy (14kWh) in a vehicle can be used for other purposes.

Figure 5: A prototype electric vehicle KaipanVoltAge K0.

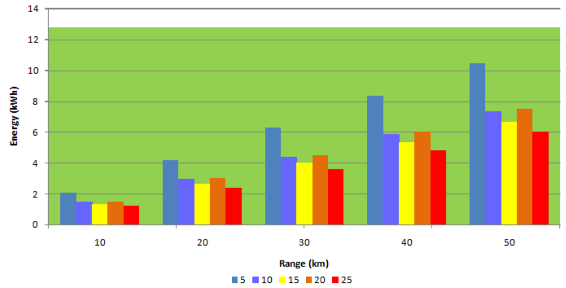

Figure 6: Consumption of electricity electric vehicle depending on the distance and temperature.

1.1.4 Energy Implemented Household

These alternative sources covered own consumption of the house to more effectively manage energy processes in the household (washing the dishes in the dishwasher, laundry, water heating, etc.).

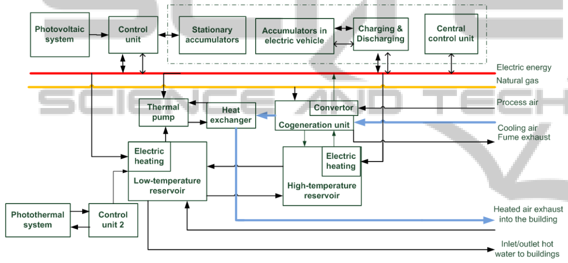

Figure 7: Block diagram of the concept of energy-independent family house.

This control requires a certain amount of prediction on the side electric vehicle and consumption household. This control system should to avoid unwanted situations which could endanger or limit the functionality of named household.

The consumption in a household can be planning. This system is called Side Demand Management (SDM) and allows the usage management by postponing consumption. Friedrischkova, K.,Workshop, 2014.

2 REALIZATION

The use electric vehicles as a backup energy source for houses requires high quality and stable battery.

The most commonly traction batteries the used in electric vehicles are Lithium Iron Phosphate.

Phosphate based technology possesses superior thermal and chemical stability which provides better safety characteristics than those of Lithium-ion technology made with other cathode materials. Lithium phosphate cells are incombustible in the event of mishandling during charge or discharge, they are more stable under overcharge or short circuit conditions and they can withstand high temperatures without decomposing. When abuse does occur, the phosphate based cathode material will not burn and is not prone to thermal runaway. Phosphate chemistry also offers a longer lifecycle.

Phosphates significantly reduce the drawbacks of the Cobalt chemistry, particularly the cost, safety and environmental characteristics. Once more the trade off is a reduction of 14% in energy density, but higher energy variants are being explored.

Due to the superior safety characteristics of phosphates over current Lithium-ion Cobalt cells, batteries may be designed using larger cells and potentially with a reduced reliance upon additional safety devices.

The performance of Lithium Ion cells is dependent on both the temperature and the operating voltage. If thresholds are exceeded may be partially or permanent damage to the cells or even their destruction. WOODBANK COMMUNICATIONS, 2005.

2.1 Testing the Battery Cell LiFePo

Testing of the battery is performed during cyclic charging and discharging while balancing the system. Use it to determine the number of cycles the batteries hold until they have the appropriate characteristics. It consists of laboratory resources, electronic measuring decade and computer.

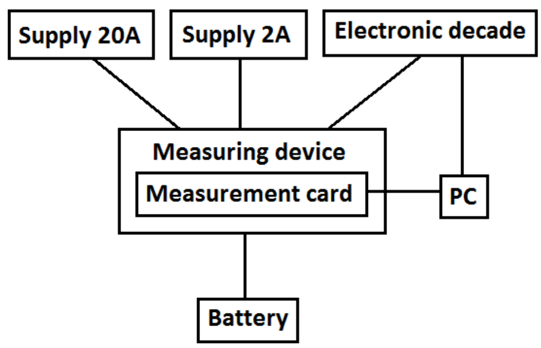

Figure 8: Block diagram testing devices for charging and discharging batteries.

The testing device serves as charging and discharging power through electronic decade. One of the charging sources has to charge using the large current and a second small current. Charging a small current is used for charging multiple batteries and is only used to recharge the batteries when charging and battery balancer has limits. Discharge electronic decade can be firmly set on the discharge current or adjusted continuously according to the required parameters during the discharge.

The process control computer is used to program measuring card in LabVIEW. Measuring card controls the measuring device and the relay to switch between charging and discharging of the battery. KAZARIK, J., 2010.

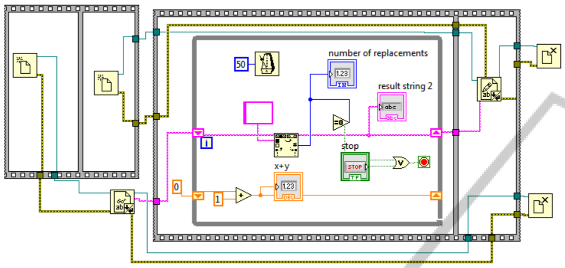

Figure 9: The measurement program for testing batteries.

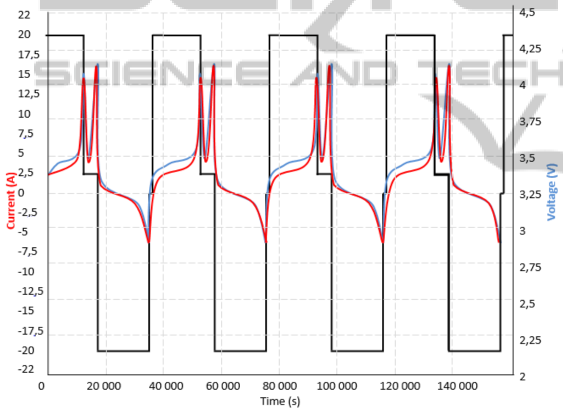

Figure 10: Lifetime battery cells.

On the Figure 10 is showing that charging has two parts - charging of battery and balancing of battery. For charging 9 Amps were used from mains (i.e 2 kW - limited by local power net). After the first, cell of traction battery charged to charging voltage (in this case 3.8V) the charger was switched by balancing subsystem to balancing mode (i.e less than 2.5A) next it is possible to observe cyclical interruption of balancing current. This is caused by necessity of heat transfer from balancing module to the cooling medium (air) and also give a time to chemistry of battery to better absorption of energy (pulse charging).

Furthermore, long-term tests of the battery cells were performed in order to verify of capacity decrease by 10% after 3000 cycles which was declared by manufacturer.

One of the main things extending the life time of the battery is a battery management system.

2.2 Battery Management System

One of the main functions of the BMS is to keep the cells operating within their designed operating window. This is not too difficult to achieve using safety devices and thermal management systems. As an additional safety factor, some manufacturers set their operating limits to more restricted levels indicated by the dotted lines. MGM COMPRO.

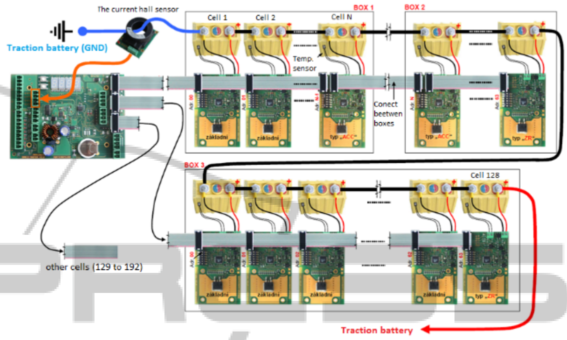

Figure 11: Battery management system in electric vehicle. MGM COMPRO.

There is however very little the BMS can do to protect against an internal short circuit. The only action that can be taken to protect it, is strict process control of all the cell manufacturing operations.

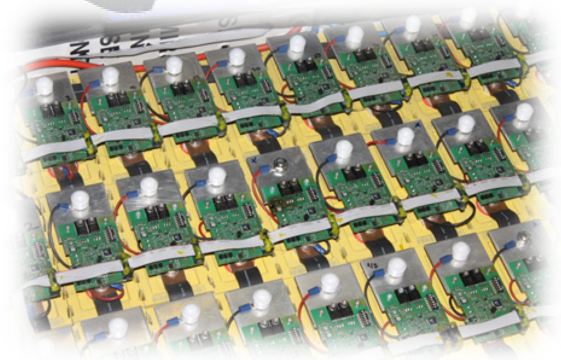

Figure 12: Installed BMS.

BMS systems developed by the company MGM compro didn't fulfill function properly due to poor cooling system.

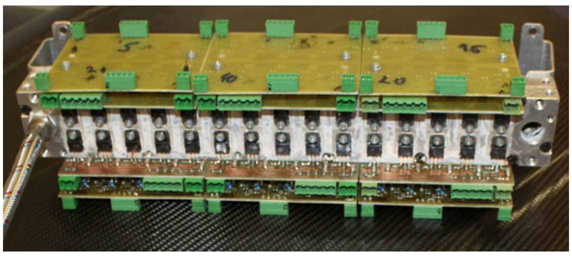

Figure 13: BMS VSB TUO water cooling.

BMS system designed for VSB Technical University of Ostrava is cooled by water and thus there is no overheating of the control elements of balance units.

Individual self-balancing / measuring units are connected to the individual battery cells and are controlled by the basic management unit, which constantly communicate.

The control unit, besides controlling balancers, also mediates the measurement of voltage, temperature, currents, safety disconnect, communicate with charger, communication with the controller (s) engines, communication with the operator.

2.3 Connections Electric Vehicle with House

Depending on the usage, renewable and alternative sources a very good aspect of electric vehicle traction battery to store excessive energy. Systems placed in both automobiles and houses are communicating and as such allowing for effective charging and discharging of traction batteries based on the needed range of the car, supplementary need of the house grid and such.

For this to be possible bidirectional transmission of electric power it is necessary to use a special protocol to be integrated into components that can be deployed in both electric and house system. One possibility is to use commercially available CHAdeMO protocol.

This protocol ensures transmission of DC electrical power from accumulators in a electric vehicle to the houses electrical grid, where the energy is converted to AC for home usage.

These electric vehicles are carrying sophisticated route planning system that includes advanced measuring, computing and storage. This system is able to guarantee possibilities of using this vehicle for transportation even if the vehicle is connected as part of energetic system of the building and part of its energy is discharged to cover energy demands.

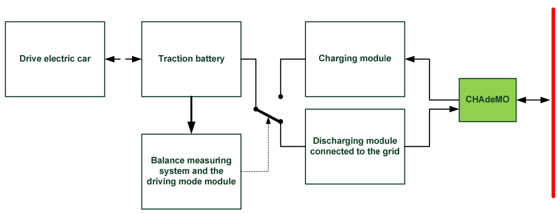

Figure 14: Block diagram of the internal concept electric vehicle and its connection to the electricity grid house.

Through the CAN communication network which is included in CHAdeMO standard, data are transferred from the vehicle to the building control system which then route the energy as required. This control system is able to cover all energy demands of building by combining different renewable alternative energy sources and electrical appliances without necessity to be connected to the public grid.

2.4 Charging of the Electric Vehicle

Traction batteries in the electric vehicle are equipped by integrated charger and balancing subsystem to be able to store electric energy. This type of charger has been subjected to series of tests in severe conditions including eg. EMC, EMI, electric safety etc. This charger is able to charge up 100A to 100 LiFePo cell battery pack.

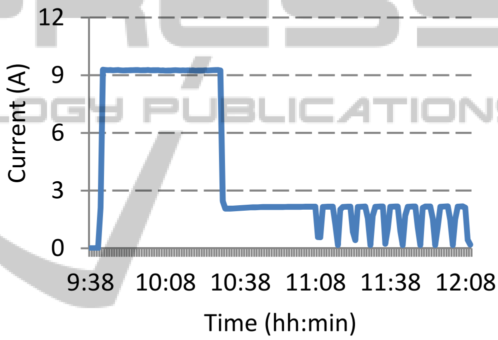

Figure 15: Charging electric vehicle.

In our experiment,the current for charge was 9A. It is optimal for the used battery (LiFePo - 40Ah) and a typeBMS of electric vehicles KaipanVoltAge K0.

2.5 Discharging of the Electric Vehicle to the Grid

The concept described above was experimentally verified by the connection of electric vehicle to the infrastructure of family house. Measurement was aimed to different setting of discharging circuit and mainly on several limitations of discharging of traction battery of electric vehicle. For the testing the minimum voltage has been setup for the traction battery to the 319 V and maximum power to the mains to the 2 kW

The graph shows the progress of power limitation depending on the state of stress on the battery.

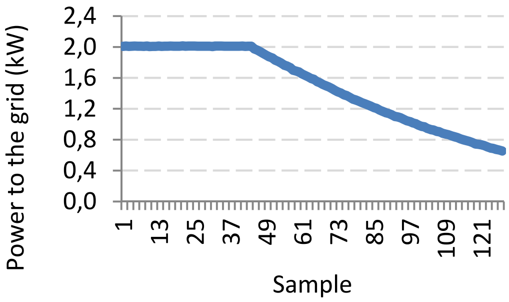

Figure 16: Discharging electric vehicle.

3 CONCLUSIONS

Usage of the new technologies and energy sources are a viable way for the people to get rid of the dependancy on international companies and state regulatory charges.

Weather profile, property size, location, orientation, these are just few things we need to take into account and together with appliances and behavioral statistics of the occupants it is much easier to create a proper list of energy sources and their optimal implementation. Most common method of self sustained renewable energy is photovoltaic, but with its impractical energy generation times, we need to establish a way to store that energy for later use in more convenient time schedules. Part of the way to increase efficiency is to combine storage of the energy with backtracking it back into public electrical grid.

Most convenient method is backtracking of the energy into the public grid, but only in case, that the buyout price is higher than selling price. Unfortunately it is not a rule and different countries have different approach to renewable energy sources that delivers into the public grid, which needs to be taken into account. We also need to understand that backtracking is not without its own risks and it can easily affect whole parts of the public grids if done improperly. There are lot of cases of public grid overloads and pullouts due to uncontrolled energy distribution from photovoltaic sources and this problems are multiplying at an alarming rate these days.

One of the way to utilize all the generated energy is to store it into accumulation units. We can find a lot of possible candidates for this function, starting with electrochemical accumulators, capacitors, supercapacitors up to the byproducts such as hydrogen, heat or cold. All of the variants above are a significant financial investments and they all bring their own issues, most commonly energy losses. Thanks to the boom of automotive industry, we could say, that most advanced and also easily accessible are electrochemical accumulators that in state of the art can go through up to 8k cycles with 20% capacity drop and without memory effect.

In case of combined ecological and economical approach we can go as far as purchase of the electromobile, that when price considered surpasses the standard middle class vehicle, but its running and maintenance costs are very low and has no demands on special treatments. Also it can be used as a supplemental accumulation unit for the family house that, in case of the implementation of the sophisticated control system, will then operate both as consumer and supplier of the energy into the family house grid and can compensate for energy generation inconsistencies.

Some experts do claim that this way of storing energy into mobile solutions is contra productive, because of the fact, that in most times that there is an energy production peak, the electromobile is usually away from the house. In this case we need to take into consideration fact, that both car and houses energy center can be in constant communication via remote access. Only necessity in this case is the connection of the car into public grid, which then may be used as a "transfer medium".

Obvious disadvantage of this technology is its entry costs, that varies based on the technologies used, where return rate is from 6 to 12 years or more. Also a big issue may be laws and regulations of the particular country, as well as common approach to this technology.

ACKNOWLEDGEMENTS

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REFERENCES

Horak, B., Minarik, D., Friedrischkova, K., Vala, D., Kazarik, J.: The development of drive units for electric cars KaipanVoltAge. Proceedings of the 14th International Scientific Conference Electric Power Engineering 2013. VŠB – TU Ostrava 2013. 978-80-248-2988-3.

Urban, H.: Eigenverbrauchimhaushalt und integration eines E-Fahrzeuges, EMobile plus solar Nr.89/2013 page 27-32. Schletter GmbH [cit. 2014-02-12]. Available from: http://www.schletter.de.

Haluza, M., Macháček, J.: Spotřeba elektrické energie domácností, predikce a potenciální úsporypomocí BACS. TZB info: Technická zařízení budov [online]. 7.5.2012, [cit. 2014-07-15]. Available from: http://elektro.tzb-info.cz/8570-spotreba-elektricke-energie-domacnosti-predikce-a-potencialni-uspory-pomoci-bacs.

Polanecký, K., Bursa, J.: Jak využívat obnovitelné zdroje energie, Praktický rádce pro domácnost a obce. 2002 [cit. 2010-05-13]. ISBN 80-902823-6-9.

梁一桥, 许挺 (names of authors). Modular charging/discharging system of power battery pack of multifunctional electromobile [patent].Patent, CN 102025182 A. Uděleno 20.4.2011. [cit. 2014-05-12]. Available from: http://www.google.com/ patents/CN102025182A?cl=en.

Friedrischkova, K., Horak, B., Dočekal,T.: Management of energy systems combined with renewable or alternative energy resources.Ph.D. Workshop of Faculty of Electrical Engineering and Computer Science. Workshop doktorandů Fakulty elektrotechniky a informatiky. VŠB - TU Ostrava 2014.

MGM COMPRO, Srovnání balančních systémů. [6.1.2012]. Available from: http://mgm-compro.cz/pdf/balancery-srovnani-d120507.pdf.

WOODBANK COMMUNICATIONS LTD,.The electropaedia [online]. 2005. vyd. South Crescent Road, Chester, CH4 7AU, (United Kingdom), 2005 [cit. 2015-01-31]. Available from: http://www.mpoweruk.com/index.htm.

M. Swierczynski, D. Stroe, and et al., "Field tests experience from 1.6MW/400kWh Li-ion battery energy storage system providing primary frequency regulation service," IEEE 4th European Innovative Smart Grid technologies, in press, 2013.

B. Dunn, H. Kamath, and et al., "Electrical energy storage for the grid:a battery of choices," Science, pp. 928–35, 2011.

Swierczynski, Maciej, Ana-Irina Stan a Remus Teodorescu. 2013. (6825 - 6830): 6. Available from: http://ieeexplore.ieee.org/xpl/login.jsp?tp=&arnumber=6700262&url=http%3A%2F%2Fieeexplore.ieee.org%2Fiel7%2F6683943%2F6699103%2F06700262.pdf%3Farnumber%3D6700262.

WEI, Liu. 2013. Introduction to Hybrid Vehicle System Modeling and Control [online]. The book. Canada [cit. 2015-05-12]. ISBN 978 - 1 - 118 - 30840 - 0. Available from: https://books.google.cz/books?id=sVgVbG5WtYkC&pg=SA5-PA51&lpg=SA5-PA51&dq=SOC+operating+window&source=bl&ots=oQktt-Rhpe&sig=1LtCyjxo2lFDAL7iESge6MtHxjc&hl=cs&sa=X&ei=XzZQVaDWLIGzUMurgdgO&redir_esc=y#v=onepage&q=SOC%20operating%20window&f=false.

Conducted By Group Wps4 - 1050. 2011. Accelerated Life Testing And Life Prediction Of Lithiu Ion Batteries Connected To Wind Turbine: Accelerated life testing and life-time prediction of Lithium Ion batteries connected to Wind Turbine [online]. Aalborg University [cit. 2015-05-12]. Dostupné z: http://projekter.aau.dk/projekter/files/52684684/Report_WPS4_1050.pdf. Student Report. Aalborg University.

Photovoltaic Geographical Information System – Interactive Maps [online]. 2015 [cit. 2015-04-15]. Available from: http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php.

Kazarik, J., Slanina, Z., Vala, D., Long - Time Battery Testing. VSB – TU Ostrava, Faculty of Electrical Engineering and Computer Science, Department of Cybernetics and Biomedical Engineering, 17. Listopadu 15, Ostrava - Poruba, Czech republic, 2010.