Active and reactive power support of MV distribution systems using battery energy storage

Adoption of Battery Energy Storage Systems (BESSs) for provision of grid services is increasing. This paper investigates the applications of BESS for the grid upgrade deferral and voltage support of Medium Voltage (MV) distribution systems. A BESS is modelled in Matlab/Simulink to perform peak load shaving and voltage support service from the perspective of Distribution System Operators (DSOs). An active power support algorithm is implemented and the effects of various load profiles as well as different Photovoltaic (PV) penetration scenarios on the operation of BESS and the optimal BESS converter size for peak load shaving are investigated. The BESS annual lifetime degradation is also estimated using a rainflow counting algorithm. A reactive power support algorithm embedded with Q-U droop control is proposed in order to reduce the voltage drop in a part of 10 kV distribution network of Nordhavn in Copenhagen, and the effects of active and reactive power support by BESS on the grid voltage are investigated.
Active integration of electric vehicles in the distribution network - theory, modelling and practice

Increasing environmental concerns are driving an evolution of the energy system, in which the electrification of the transport sector is considered to be a crucial element. Successful electric vehicle (EV) introduction potentially allows the reduction of CO2 emissions, but also represents a substantial challenge for the power system, especially at the distribution level where high EV concentrations cause various detrimental effects. More specifically, the low-voltage grid operation becomes challenging since uncontrolled EV charging typically coincides with the peak residential consumption, resulting in a considerable peak load and severe voltage deviations. However, EVs hold potential for providing services beyond transportation and, thus, should not be considered merely as passive loads. If managed properly, EVs become flexible resources which can enhance the grid operation, making them an attractive asset for the distribution system operator (DSO). This thesis investigates how EVs can mitigate the self-induced adverse effects and actively help the distribution grid operation, either autonomously or in coordination, e.g., with an EV aggregator. The general framework for EV integration is presented, including the contemporary technology, the relevant stakeholders and the most important challenges. EV flexibility provision to DSOs is studied both from the technical and the regulatory perspective in order to identify the barriers for active EV involvement, and provide a set of policy recommendations for overcoming them. The potential benefits and drawbacks of introducing EV reactive power capability for voltage support are analysed. A decentralised reactive power control is proposed which can, given the appropriate equipment sizing, support the distribution grid independent of the active power modulation. Such an autonomous controller relies only on the local voltage measurement and can be implemented in the short-term future by using the inherent functionality of the EV power electronics. The impact of the proposed control is investigated on a Danish low-voltage grid with the assessment of grid parameters in various conditions. A multi-objective framework is developed for the optimal EV day-ahead scheduling in unbalanced distribution grids. The framework assesses the trade-off between the DSO’s and the EV aggregator’s economic concerns, and uses a fuzzy-satisfying method to balance the interest of both parties. Moreover, the impact of the additional EV reactive power support is analysed when EVs are the only flexible resource, as well as when combined with other demand response. Experimental activities were conducted to validate the technical feasibility of contemporary EVs to provide flexibility services, both in a laboratory environment and in a real distribution grid. The emphasis was put on assessing several EV parameters, such as EV responsiveness and EV accuracy, to provide basis for future theoretical work, as well as recommendations for improvement. Overall, it is shown that EVs can actively support the distribution grid operation without substantially influencing the losses or the EV aggregator’s cost. Finally, it is proven that series-produced EVs are capable of providing various flexibility services within several seconds, but their accuracy might arise as a topic of concern.
electric energy storage options, are investigated. A conclusion is drawn with a summary of experiences and lessons learned in Denmark related to wind power development.

**General information**

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Organisations: Department of Electrical Engineering, Center for Electric Power and Energy, Distributed energy resources, Energy system management
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Cost-Benefit Analysis of a Novel DC Fast-Charging Station with a Local Battery Storage for EVs

The increasing penetration of Electric Vehicles (EVs) and their charging systems is representing new highpower consumption loads for the distribution system operators (DSOs). To solve the problem of the EV range in terms of driving kilometers, the car manufacturers have invested resources on new EV models by increasing the size of the batteries. To satisfy EV load demand of the new EV models in urban areas the public DC Fast-Charging Station (DCFCS) is indispensable to recharge EVs rapidly. The introduction of the Battery Energy Storage within the DCFCSs is considered in this paper an alternative solution to reduce the operational costs of the charging stations as well as the ability to mitigate negative impacts during the congestion on the power grids. An accurate description of the DCFCS and its design system, which is able to decouple the peak load demand caused by EVs on the main grid and decrease the connection fees. Finally, an economic evaluation is done to evaluate the feasibility and the cost-benefit analysis (CBA) of the DCFCSs. The proposed approach considers various technical and economic issues, such as cost of installation, connection fees and life cycle cost of the batteries. The proposed cost-benefit analysis can be used to verify the effectiveness and applicability of DCFCS in large scale.

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Organisations: Department of Electrical Engineering, Center for Electric Power and Energy, Energy resources, services and control
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Battery energy storage, Cost-benefit analysis, Fast charging station, Electric vehicles, Market design
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Electric Vehicles (EVs) are representing a great opportunity for major car manufacturers to invest resources in new technologies in order to support sustainable transportation and the reduction of CO2 emissions, in particular in the metropolitan areas. In recent years, the increasing penetration of EVs and their charging systems are going through a series of changes. This paper addresses the design of a new DC Fast Charging Station (DCFCS) for EVs coupled with a local Battery Energy Storage (BES) by using the IEC 15118, which provides a communication interface among different actors. DCFCS is equipped with a bidirectional AC/DC converter for feeding power back to the grid, two lithium batteries and a DC/DC converter. The proposed solution decreases the charging time of EVs and facilitates the integration of fast chargers in existing low voltage (LV) grids. The charging station can also be used as a multifunctional grid-utility for ancillary services such as primary frequency control, load levelling and congestion management.

Energylab Nordhavn: An integrated community energy system towards green heating and e-mobility
This paper analyzes the green potential of a newly developed urban community, i.e., Nordhavn, in Copenhagen, Denmark from a planning perspective, wherein the energy sector of power, heat and transportation will be developed as an integrated energy system solution. Based on an hour-by-hour analysis wherein the generation and demand in each energy sector are balanced, the analysis explains how different levels of penetration of centralized heat pumps (HPs) and electric vehicles (EVs) would influence the energy performance of this integrated community energy system. The performance of the integrated energy system is evaluated from the perspectives of annual fuel consumption, electricity import, system cost and CO2 emission, etc.
Enhancing Wind Power Integration through Optimal Use of Flexibility in Multi-Carrier Energy Systems from the Danish Perspective

Denmark’s goal of being independent of fossil energy sources in 2050 puts forward great demands on all energy subsystems (electricity, heat, gas and transport, etc.) to be operated in a holistic manner. The Danish experience and challenges of wind power integration and the development of district heating systems are summarized in this paper. How to optimally use the cross-sectoral flexibility by intelligent control (model predictive control-based) of the key coupling components in an integrated heat and power system including electrical heat pumps in the demand side, and thermal storage applications in buildings is investigated.

Guidelines for Distribution System Operators on Reactive Power Provision by Electric Vehicles in Low Voltage Grids

The increasing success of electric vehicles is bringing new technical challenges to power system operators. This work intends to provide guidelines for distribution system operators in terms of reactive power requirements when evaluating and authorizing electric vehicles supply equipment with fast charging capability in existing low voltage distribution feeders. The aim is to prevent the voltage to exceed the permitted values when charging at high power, by exploiting the effect of the reactive power. The proposed guidelines for distribution system operators are reported in a matrix, which indicates the amount of reactive power that an individual electric vehicle is expected to provide when connected to a low voltage feeder, in order to benefit of the desired voltage rise in comparison to the case of unitary power factor.
Optimal Design of DC Fast-Charging Stations for EVs in Low Voltage Grids

DC Fast Charging Station (DCFCS) is essential for widespread use of Electric Vehicle (EVs). It can recharge EVs in direct current in a short period of time. In recent years, the increasing penetration of EVs and their charging systems are going through a series of changes. This paper addresses the design of a new DCFCS for EVs coupled with a local Battery Energy Storage (BES). DCFCS is equipped with a bidirectional AC/DC converter for feeding power back to the grid, two lithium batteries and a DC/DC converter. This paper proposes an optimal size of the BES to reduce the negative impacts on the power grid through the application of electrical storage systems within the DC fast charging stations. The proposed solution decreases the charging time and the impact on the low voltage (LV) grid significantly. The charger can be used as a multifunctional grid-utility such as congestion management and load levelling. Finally, an optimal design of the DCFSC has been done to evaluate the feasibility and the operability of the system in different EVs load conditions.
Setting the foundations for international and crossdisciplinary learning: The US-Denmark Summer School "Renewable Energy: In Practice"

The grand challenges posed by global climate change, scarce natural resources, and the volatility of the international energy market require targeted action towards finding technologically, economically, and socially viable solutions based on renewable energy generation and sustainable practice. As such, impactful innovation requires skills and interactions beyond that available in traditional, single track curriculum.

The U.S.-Denmark Summer Workshop on Renewable Energy is a unique educational initiative developed by several universities in Denmark and California to address these themes and foster a holistic and creative mind set. The three-week workshop takes place annually, alternating each summer between California and Denmark, and is open to selected students from US and European Universities. The program is preceded by a week of online preparation, where students utilize video conferencing and other tools to facilitate interaction between the international participants and learn more about the communities and technologies involved. A primary focus of the program is experiential learning through diverse and cross-cultural interactions, with participants coming not only from the US and Denmark, but also over a dozen other countries. The program introduces and reinforces a holistic approach to sustainable development by offering access to leading experts in politics, economics, science, and technology in parallel with multi-disciplinary, client-oriented projects. Participants are either senior undergraduate/graduate students and more recently, professionals representing different disciplines. Faculty, mentors, and participants interact daily while exploring currently implemented technological solutions and their limitations through community and industrial site visits, seminars, and real-world case studies. Students apply these learnings by collaborating in bi-national team-based projects performing feasibility studies for specified clients. The close collaboration with local communities, businesses, and industry to provide concrete solutions to an identified problem while engaging across disciplines cultivates entrepreneurially-minded and complex systems thinking necessary for innovation.

Over the eight years of the summer school, a number of lessons have been learned regarding effective program design and assessment. In this proceeding, we will elaborate on these learnings through participant feedback and faculty observations, to articulate a detailed program design that accounts for some of the challenges inherent to multi-national and multi-cultural collaborations with real-world impact.

General information
State: Published
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Supporting involvement of electric vehicles in distribution grids: Lowering the barriers for a proactive integration

Increasing environmental concerns are driving an evolution of the energy system in which electric vehicles (EVs) play an important role. Still, as the EV number increases, the adverse impact of charging is observed more widely, especially at the low-voltage level where high EV concentrations cause various detrimental effects due to the coincidence between EV charging and residential peak load. However, if managed properly, EVs become flexible resources which can improve the system operation, making them an attractive asset for the distribution system operator. With the recent technology development, new forms of local EV support can be developed, provided that an appropriate regulatory framework is established. Whereas the technical value of such EV distribution grid services has already been proven, integrating them into the European regulatory context is not straightforward. In the context where active distribution grid management schemes are still to be developed, it is important to recognise the barriers for active EV involvement in the early stage of the development. This manuscript focuses on identifying these barriers from a technology and infrastructure perspective as well as from the regulatory and market aspect. Various policy recommendations are provided for the stakeholders involved in the EV value chain.

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Organisations: Department of Electrical Engineering, Center for Electric Power and Energy, Energy resources, services and control
Authors: Knezovic, K. (Intern), Marinelli, M. (Intern), Zecchino, A. (Intern), Andersen, P. B. (Intern), Træholt, C. (Intern)
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Pages: 458-468
Algebraic Varieties and System Design
Design and analysis of networks have many applications in the engineering sciences. This dissertation seeks to contribute to the methods used in the analysis of networks with a view towards assisting decision making processes. Networks are initially considered as objects in the category of graphs and later as objects in the category of hypergraphs. The connection with the category of simplicial pairs become apparent when the topology is analyzed using homological algebra. A topological ranking is developed that measures the ability of the network to stay path-connected. Combined with the analysis of cover ideals of hypergraphs, the topological ranking demonstrates the non-trivial decisions that needs to be considered in system design. All the methods developed here have an underlying common structure, namely that they all appear at solution sets for systems of polynomials. These solution sets are called algebraic varieties.

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Organisations: Department of Electrical Engineering, Center for Electric Power and Energy, Energy resources, services and control, Department of Applied Mathematics and Computer Science, Cognitive Systems, Software Engineering
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Relations
Projects:
Algebraic Varieties and System Design

Evaluation of Electric Vehicle Charging Controllability for Provision of Time Critical Grid Services
Replacement of conventional generation by more stochastic renewable generation sources leads to reduction of inertia and controllability in the power system. This introduces the need for more dynamic regulation services. These faster services could potentially be provided by the growing number of electric vehicles. EVs are a fast responding energy resource with high availability. This work evaluates and experimentally shows the limits of EV charging controllability with the focus on its suitability for providing ancillary grid services. Three different series produced EVs are tested. The experimental testing is done by using charging current controllability of built-in AC charger to provide a primary frequency regulation service with very dynamic input frequency. The results show that most the controllability of most EVs is more than suitable for providing time critical grid services. Meanwhile, charging current ramping rates of recently produced EVs are potentially suitable to provide synthetic inertia.

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Organisations: Department of Electrical Engineering, Center for Electric Power and Energy, Energy resources, services and control
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Electric Vehicles, Charging Stations, Power Control, Smart Grid
Topological Rankings in Communication Networks

In the theory of communication the central problem is to study how agents exchange information. This problem may be studied using the theory of connected spaces in topology, since a communication network can be modelled as a topological space such that agents can communicate if and only if they belong to the same path connected component of that space. In order to study combinatorial properties of such a communication network, notions from algebraic topology are applied. This makes it possible to determine the shape of a network by concrete invariants, e.g. the number of connected components. Elements of a network may then be ranked according to how essential their positions are in the network by considering the effect of removing them. Defining a ranking of a network which takes the individual position of each entity into account has the purpose of assigning different roles to the entities, e.g. agents, in the network. In this paper it is shown that the topology of a given network induces a ranking of the entities in the network. Furthermore, it is demonstrated how to calculate this ranking and thus how to identify weak sub-networks in any given network.

General information
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A Decentralized Storage Strategy for Residential Feeders with Photovoltaics
This paper proposes a decentralized voltage support strategy for LV residential feeders with high roof-top PV capacity installed. The proposed strategy is capable of increasing the local consumption at private households with PV during high generation periods, by the use of locally controlled domestic energy storage systems (ESS). The traditional way of operating a domestic ESS to increase the local consumption rate does not take into account the need of voltage support in a feeder; the proposed storage concept improves the traditional one, by mitigating voltage rise due to PV in the feeder. The power sizing of the ESSs is performed with linear programming (LP) method, based on voltage sensitivity analysis. A Belgian residential LV feeder with private PV systems is used as a case study to demonstrate the effectiveness of the proposed strategy. Quantification of the required energy levels for the ESSs and estimation of LV grid losses is performed by means of time-series simulation using 1-year load and generation profiles.

General information
State: Published
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A Dynamic Behaviour Analysis on the Frequency Control Capability of Electric Vehicles
The paper presents results of a study on the dynamic response of Electric Vehicle's (EV) when participating in frequency control of an islanded system. The following cases were considered: when there is no EV performing frequency control,
when the EV participates in primary frequency control and when the EV participates in both primary and secondary
frequency control. Different parameters are tested in various combinations, and their influence on frequency deviation as
well as power and energy provided by the EV with vehicle-to-grid (V2G) capability is shown.

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Analysis of Voltage Support by Electric Vehicles and Photovoltaic in a Real Danish Low Voltage Network
With conventional generating units being replaced by renewable sources which are not required to provide same high
level of ancillary services, there is an increasing need for additional resources to achieve certain standards regarding
frequency and voltage. This paper investigates the potential of incorporating electric vehicles (EVs) in a low voltage
distribution network with high penetration of photovoltaic installations (PVs), and focuses on analysing potential voltage
support functions from EVs and PVs. In addition, the paper evaluates the benefits that reactive power control may provide
with addressing the issues regarding voltage control at the expense of increased loading. Analysed real Danish low
voltage network has been modelled in Matlab SimPowerSystems and is based on consumption and PV production data
measured individually for number of households.

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Organisations: Department of Electrical Engineering, Center for Electric Power and Energy, Technical University of
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Relations
Concurrent Provision of Frequency Regulation and Overvoltage Support by Electric Vehicles in a Real Danish Low Voltage Network

Expected deployment of electric vehicles (EVs) introduces big technical challenges for power system operation, but also offers advantages provided that EVs are not considered merely as passive loads. With the development of Vehicle-to-Grid technology, EVs will be able to provide a number of ancillary services for grid support, e.g. implemented electronic equipment will allow them to exchange reactive power with the grid for voltage regulation while using active power for other services. This paper investigates the concurrent provision of local and system wide services from EVs in a real Danish low voltage network with high penetration of photovoltaic installations (PVs). The main focus is potential reactive power support when EV provision of frequency regulation coincides with PV production. Furthermore, the paper evaluates benefits of overvoltage support and addresses the issue of increased loading. The analysed network has been modelled in Matlab SimPowerSystems and is based on real hourly metered data from a Danish MV/LV substation with numerous households.

Electric Vehicle Smart Charging using Dynamic Price Signal

With yearly increases in Electric Vehicle (EV) sales, the future for electric mobility continues to brighten, and with more vehicles hitting the roads every day, the energy requirements on the grid will increase, potentially causing low-voltage distribution grid congestion. This problem can, however, be resolved by using intelligent EV charging strategies, commonly referred to as "Smart Charging". The basic approach involves modifying the default vehicle charging scheme of "immediate charging", to a more optimal one that is derived from insight into the current state of the grid. This work proposed in this paper, involves a real-time control strategy for charging the EV using a dynamic price tariff, with the objective of minimizing the charging cost. Two different charging scenario are investigated, and the results are verified by experiments on a real Electric Vehicle. Finally, the costs of the proposed solutions are compared to the default charging scheme.
Implementation and Demonstration of Grid Frequency Support by V2G Enabled Electric Vehicle

Safe operation of the electric power system relies on conventional power stations. In addition to providing electrical energy to the network, some power stations also provide a number of ancillary services for the grid stability. These services could potentially be provided by the growing number of electric vehicles - faster and with better precision, using Vehicle-to-Grid technology. This paper explores the implementation of a system that demonstrates the use of the electric vehicles for providing frequency regulation in the Danish power grid. The system is tested with the use case of Primary Frequency Regulation. The service is implemented following the technical conditions for ancillary services in the Danish grid. The real life system is developed using web-centric communication technologies between the components. Communication and control functions of the system are validated through experiments. The response of the system is studied in terms of latency, precision and stability.

General information
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Ranking Entities in Networks via Lefschetz Duality
In the theory of communication it is essential that agents are able to exchange information. This fact is closely related to the study of connected spaces in topology. A communication network may be modelled as a topological space such that agents can communicate if and only if they belong to the same path connected component of that space. In order to study combinatorial properties of such a space, notions from algebraic topology are applied. This makes it possible to determine the shape of a network by concrete invariants, e.g. the number of connected components. Elements of a network may then be ranked according to how essential their positions are in the network by considering the effect of their respective absences. Defining a ranking of a network which takes the individual position of each entity into account has the purpose of assigning different roles to the entities, e.g. agents, in the network. In this paper it is shown that the topology of a given
network induces a ranking of the entities in the network. Further, it is demonstrated how to calculate this ranking and thus how to identify weak sub-networks in any given network.

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Organisations: Department of Electrical Engineering, Center for Electric Power and Energy, Energy resources, services and control, Department of Applied Mathematics and Computer Science, Cognitive Systems, Software Engineering
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Superconducting wind turbine generators
A HTS machine could be a way to address some of the technical barriers offshore wind energy is about to face. Due to the superior power density of HTS machines, this technology could become a milestone on which many, including the wind industry, will rely on in the future. The work presented in this thesis is a part of a larger endeavor, the Superwind project that focused on identifying the potentials that HTS machines could offer to the wind industry and addressing some of the challenges in the process. In order to identify these challenges, I have designed and constructed an HTS machine experimental setup which is made to serve as precursor, leading towards an optimized HTS machine concept proposed for wind turbines. In part, the work presented in this thesis will focus on the description of the experimental setup and reasoning behind the choices made during the design. The setup comprises an HTS synchronous machine where a revolving armature winding spins around an open bath liquid nitrogen cryostat, which contains the HTS coils cooled down to 77 K. A significant part of the thesis is allocated to the description of the setup, particularly the torque transfer element and the compact cryostat design, where a concept with 20 W of heat transfer is achieved. Following the setup description, the focus turns to the electromagnetic design of the HTS machine. Particularly, an approach to increase the performance of HTS coils and the influence of the armature reaction to the HTS field winding will be discussed. Two design strategies are proposed, novel in a machine design, in order to reduce the amount of HTS required in a machine whereby the merits of both have been experimentally verified. The first employs a multiple HTS types in the machine design, since each type of the HTS tape has a specific magnetic characteristic with respect to the critical current. I have showed that the potential for the reduction of HTS conductor can be significant, if the coils are placed strategically, whereby the coils wound with BSCCO performed 40% better depending on the placement in the field winding. The 2G coils were less sensitive to the placement which made them particularly useful for high magnetic field regions in the end winding. The second design approach proposed and tested was to use multiple current supplies which allowed each coil to operate close to its critical current. I have demonstrated that by introducing one additional power supply, an order of 12% higher MMF was generated (or equivalent HTS savings achieved). Increasing in the number of additional power supplies did not show the same potential for HTS reduction. The implications of an armature reaction impact on the HTS field Winding performance were examined and verified throughout a series of Locked Armature experiments. The interaction have been dened in the terms of two (direct and quadrature) axis machine theory (Park transformation), where significant reduction of 20% was observed for the rated armature reaction in the q axis. Building on this observation, a control strategy for the excitation current to improve a partial load ecieny of a HTS machine is proposed. Thus, this work has shown that a signi cant savings of a costly HTS tape could be realized indicating that the HTS machine design can still be optimized towards more competitive alternative to conventional machines. Additionally, by constructing the HTS machine setup we went through most of the issues related to the HTS machine design which we managed to address in rather simple manner using everyday materials and therefore proving that HTS machines are close to commercialization.

General information
State: Published
Organisations: Department of Electrical Engineering, Center for Electric Power and Energy, Department of Wind Energy, Wind Energy Systems
Authors: Mijatovic, N. (Intern), Jensen, B. B. (Intern), Træholt, C. (Intern), Abrahamsen, A. B. (Intern)
Number of pages: 178
Electric Vehicles Integration in the Electric Power System with Intermittent Energy Sources - The Charge/Discharge infrastructure

The replacement of conventional fuelled vehicles with electric vehicles (EVs) is going to increase in the coming years, following the trend seen for renewable energy sources (RES), as photovoltaic (PV) and wind power. In this scenario, the electric power systems in Europe are going to accommodate increased levels of non-dispatchable and fluctuating energy sources, as well as additional power demand due to EV charging. If the charging of EVs can be intelligently managed, several advantages can be offered to the power system. How useful coordinated EV charging can be, in combination with RES, is answered in this research work. Two real cases are addressed:

- the EV load coordination for power fluctuations due to wind power, in the Danish power system;
- the EV load coordination for the power fluctuations due to Photovoltaic (PV) in low voltage grids, in several European countries.

The research work starts with the definition of EV requirements for enabling a bidirectional power exchange with the grid. A set of monitoring and control requirements are defined to achieve EV coordination. The validation of the defined requirements is performed with a full-scale EV test bed made of real EV components such as a lithium ion battery pack, a battery management system and charging/discharging units.

The second part of the research exploits the use of EV load coordination to facilitate the integration of wind power in the Danish power system. A proof of concept of regulating power reserves is realized, using the target power requests from the Danish Transmission System Operator (ENERGINET.DK), valid as the control signal for the EVs. The EV coordination is realized under the control framework of a Virtual Power Plant. The tests performed show that an EV can respond according to the time plan and the power levels needed. Furthermore, during EV coordination, a number of nonlinearities and battery ageing issues should be taken into account, to ensure a correct EV coordination and to preserve the EV battery lifetime.

The third part of this research exploits the use of EV load coordination as an energy storage solution to facilitate PV integration in LV distribution grids. In this context, the storage capabilities of EV charging stations are analyzed. Two concepts of stations are investigated: public charging station, to accommodate the parallel charging of EVs at public locations, and private charging stations at private homes. The coordination of EV load of public or private charging stations creates benefits in feeders with PV. A method based on voltage sensitivity analysis is proposed to evaluate the influence of EV load coordination at different locations in the grid. Time-series simulations and a proof of concept prove the usefulness of coordinating the load from EV stations in LV feeders with PV.

As a general conclusion, it is observed how important the role of EV load coordination can be, in coping with the fluctuations of renewable power sources at different power system levels.
A novel method is proposed to determine the ESS charging load required for voltage regulation and compare the results for the different locations in the feeder. With time-series simulations, we quantify the energy size required for a station ESS. A Belgian LV residential grid, modeled using real PV generation and load profiles, is used as case study. The method and simulation results show the effectiveness of using public EV charging facilities with the additional function of voltage regulation in feeders with PV.

**General information**

State: Published
Organisations: Department of Electrical Engineering, Center for Electric Power and Energy, University of Ljubljana, Infrax
Authors: Marra, F. (Intern), Yang, G. (Intern), Træholt, C. (Intern), Larsen, E. (Intern), Østergaard, J. (Intern), Blazic, B. (Ekstern), Deprez, W. (Ekstern)
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Scopus rating (2013): SJR 3.175 SNIP 4.831 CiteScore 9.88
ISI indexed (2013): ISI indexed no
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**Improvement of Local Voltage In Feeders with Photovoltaic using Electric Vehicles**

In low-voltage (LV) feeders with high penetration of photovoltaic (PV), a major issue to be solved is voltage rise due to the active power injection. If no measures are taken, this may lead to generation’s interruptions and to the malfunctioning of domestic appliances due to non-standard voltage profiles. This paper proposes a storage strategy to alleviate voltage rise in feeders with PV, using coordinated electric vehicle (EV) load as the storage solution. The voltage support strategy is easy to implement practically and it is demonstrated on a test feeder emulating a household with roof-mounted PV and an EV. The results show the effectiveness of using coordinated EV load in feeders with PV to mitigate voltage rise problems.

**General information**

State: Published
Organisations: Department of Electrical Engineering, Center for Electric Power and Energy, Technical University of Carolo Wilhelmina Braunschweig (DE), DONG Energy A/S
Integrating Intelligent Electric Devices into Distributed Energy Resources in a Cloud-Based Environment

Until now the main purpose of Distributed Energy Resources (DERs) has been to compliment the power plants. However, if DERs are to play a larger role in the power grid of the future, then improved communication and cooperation between these resources and the system operators is necessary. Cooperation requires intelligence at the level of the DER as well as at the aggregator level, and in order to efficiently facilitate this, communication must be easily achievable.

This project presents a proof-of-concept plug-and-play cloud solution for next generation DERs, built upon the IEC 61850[15] standard, that enable easy communication and cooperation between DERs and system operators.

General information
State: Published
Organisations: Department of Electrical Engineering, Center for Electric Power and Energy, Department of Applied Mathematics and Computer Science, Software Engineering, Energy system operation and management, Technical University of Denmark
Authors: Petersen, B. S. (Intern), Winther, D. (Ekstern), Pedersen, A. B. (Intern), Poulsen, B. (Intern), Træholt, C. (Intern)
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Source: dtu
Source-ID: u::10053
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Simulation Tool For Energy Consumption and Production: The development of a simulation tool for measuring the impact of a smart grid on a building

In order to promote adoption of smart grid with the general public it is necessary to be able to visualize the benefits of a smart home. Software tools that model the effects can help significantly with this. However, only little work has been done in the area of simulating and visualizing the energy consumption in smart homes. This paper presents a prototype simulation tool that allows graphical modeling of a home. Based on the modeled homes the user is able to simulate the energy consumptions and compare scenarios. The simulations are based on dynamic weather and energy price data as well as a controller unit of the user’s choice. The results of the simulations can be compared using a dynamic reporting window that allows the user to create custom charts of the data. The application has been designed such that it can easily be extended with additional controller units, price and weather data as well as appliances and other electrical components used in the modeled homes.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Software Engineering, Department of Electrical Engineering, Center for Electric Power and Energy, Technical University of Denmark
Authors: Nysteen, M. (Ekstern), Mynderup, H. (Ekstern), Poulsen, B. (Intern), Træholt, C. (Intern)
Number of pages: 8
Publication date: 2013

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An HTS machine laboratory prototype
This paper describes Superwind HTS machine laboratory setup which is a small scale HTS machine designed and build as a part of the efforts to identify and tackle some of the challenges the HTS machine design may face. One of the challenges of HTS machines is a Torque Transfer Element (TTE) which is in this design integral part of the cryostat. The discussion of the requirements for the TTE supported with a simple case study comparing a shaft and a cylinder as candidates for TTE are presented. The discussion resulted with a cylinder as a TTE design rated for a 250Nm and with more then 10 times lower heat conduction compared to a shaft. The HTS machine was successfully cooled to 77K and tests have been performed. The IV curves of the HTS field winding employing 6 HTS coils indicate that two of the coils had been damaged. The maximal value of the torque during experiments of 78Nm was recorded. Loaded with 33%, the TTE performed well and showed sufficient margin for future experiments.

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ISI indexed (2013): ISI indexed no
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Demand Profile Study of Battery Electric Vehicle under Different Charging Options
An increased research on electric vehicles (EV) and plug-in hybrid electric vehicles (PHEV) deals with their flexible use in electric power grids. Several research projects on smart grids and electric mobility are now looking into realistic models representing the behavior of an EV during charging, including nonlinearities. In this work, modeling, simulation and testing of the demand profile of a battery-EV are conducted. Realistic work conditions for a lithium-ion EV battery and battery
charger are considered as the base for the modeling. Simulation results show that EV charging generates different demand profiles into the grid, depending on the applied charging option. Moreover, a linear region for the control of EV chargers is identified in the range of 20-90% state-of-charge (SOC). Experiments validate the proposed model.

General information
State: Published
Organisations: Department of Electrical Engineering, Electric Components, Electric Energy Systems
Authors: Marra, F. (Intern), Yang, G. Y. (Intern), Traeholt, C. (Intern), Larsen, E. (Intern), Rasmussen, C. N. (Intern), You, S. (Intern)
Number of pages: 7
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Implementation of an Electric Vehicle Test Bed Controlled by a Virtual Power Plant for Contributing to Regulating Power Reserves
With the increased focus on Electric Vehicles (EV) research and the potential benefits they bring for smart grid applications, there is a growing need for an evaluation platform connected to the electricity grid. This paper addresses the design of an EV test bed, which using real EV components and communication interfaces, is able to respond in real-time to smart grid control signals. The EV test bed is equipped with a Lithium-ion battery pack, a Battery Management System (BMS), a charger and a Vehicle-to-Grid (V2G) unit for feeding power back to the grid. The designed solution serves as a multifunctional grid-interactive EV, which a Virtual Power Plant (VPP) or a generic EV coordinator could use for testing different control strategies, such as EV contribution to regulating power reserves. The EV coordination is realized using the IEC 61850 modeling standard in the communication. Regulating power requests from the Danish TSO are used as a proof-of-concept, to demonstrate the EV test bed power response. Test results have proven the capability to respond to frequent power control requests and they reveal the potential EV ability for contributing to regulating power reserves.

General information
State: Published
Organisations: Department of Electrical Engineering, Center for Electric Power and Energy
Authors: Marra, F. (Intern), Sacchetti, D. (Intern), Pedersen, A. B. (Intern), Andersen, P. B. (Intern), Traeholt, C. (Intern), Larsen, E. (Intern)
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Integration of Fuel Cell Micro-CHPs on Low Voltage Grid: A Danish Case Study.
The future significance of fuel cell (FC) powered micro combined heat and power (micro-CHP) units in meeting the residential energy demands is set to increase, which may have a considerable impact on the low voltage (LV) grid. The objective of this paper is to investigate into the related technical issues using a Danish case study with different penetration levels of uncoordinated FC micro-CHPs. Based on the findings, it is recommended to design grid oriented integration strategies such as Virtual Power Plants (VPPs) for achieving future smart grids with a large roll out of distributed energy resources (DER).

Low AC Loss in a 3 kA HTS Cable of the Dutch Project
Requirements for a 6km long high temperature superconducting (HTS) AC power cable of the Amsterdam project are: a cable has to fit in an annulus of 160mm, with two cooling stations at the cable ends only. Existing solutions for HTS cables would lead to excessively high coolant pressure drop in the cable, potentially affecting public acceptance of the project. A way out would be to substantially reduce AC losses from 1 down to about 0.1W/m per phase at rated current of 3 kArms, frequency of 50Hz and temperature of 77K. In this paper we discuss a strategy towards this ambitious goal, a concept design of the single phase cable 3 kA conductor made of YBCO tapes and present corresponding experimental and simulation data supporting the developed approach leading directly to this goal. HTS cable model was made that show a drastically reduced AC loss. The low loss was achieved by using appropriate pitch angles for two-layer cable conductor of relatively large diameter, by minimizing the gaps between the HTS tapes, and by using narrow HTS tapes that conform well to the roundness of the underlying former. AC loss of 0.12W/m at 3 kArms was measured at a frequency of 60Hz and at a temperature of 77K.
Low Friction Cryostat for HTS Power Cable of Dutch Project

Particulars of 6km long HTS AC power cable for Amsterdam project are: a cable has to fit in an annulus of 160mm, with only two cooling stations at the cable ends [1]. Application of existing solutions for HTS cables would result in excessively high coolant pressure drop in the cable, possibly affecting public acceptance of the project. In order to solve this problem, a model cryostat was developed consisting of alternating rigid and flexible sections and hydraulic tests were conducted using sub-cooled liquid nitrogen. In the 47 m-long cryostat, containing a full-size HTS cable model, measured pressure drop amounts 11 mbar at the mass flow rate of 0.3kg/s and temperature 65K. For a 6 km-long HTS cable this gives a pressure drop below 2bar, which is acceptable. In order to achieve this result, the cryostat was manufactured from alternating straight rigid sections and corrugated flexible sections. A flexible dummy HTS cable was inserted into this cryostat and sub-cooled liquid nitrogen was circulated in the annulus between the dummy cable surface and the inner cryostat surface. In the paper details are presented of the cryostat, of the measurement setup, of the experiment and of the results.

General information
State: Published
Organisations: Department of Electrical Engineering, Electric Components, Delft University of Technology, NKT Cables A/S
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Scopus rating (2012): SJR 0.293 SNIP 0.622 CiteScore 0.5
ISI indexed (2012): ISI indexed no
Measurement of AC losses in a racetrack superconducting coil made from YBCO coated conductor

We present the results of transport measurements of AC losses in a racetrack shaped superconducting coil made from coated conductor tape. The outer dimensions of the coil are approximately 24 cm × 12 cm and it has 57 turns. The coil is impregnated with epoxy resin and fiberglass tape is used to insulate the individual turns and to improve the mechanical properties of the epoxy when exposed to thermal cycling. The coil is manufactured as a part of the field winding of a small synchronous generator; therefore stainless steel frames are installed on the inner and outer side of the winding to reinforce it. The AC loss is measured versus the transport current Ia with the coil immersed in liquid nitrogen. Measurements at frequencies 21 Hz, 36 Hz and 72 Hz are compared. The AC losses follow I2 a dependence at low current amplitudes and I3 a at high amplitudes. After cutting the inner steel frame the low amplitude losses are decreased, their frequency dependence is reduced but their dependence on the current remains unchanged.

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Planning Future Electric Vehicle Central Charging Stations Connected to Low-Voltage Distribution Networks

A great interest is recently paid to Electric Vehicles (EV) and their integration into electricity grids. EV can potentially play an important role in power system operation, however, the EV charging infrastructures have been only partly defined, considering them as limited to individual charging points, randomly distributed into the networks. This paper addresses the planning of public central charging stations (CCS) that can be integrated in low-voltage (LV) networks for EV parallel
charging. The concepts of AC and DC architectures of CCS are proposed and a comparison is given on their investment cost. Investigation on location and size of CCS is conducted, analyzing two LV grids of different capacity. The results enlighten that a public CCS should be preferably located in the range of 100 m from the transformer. The AC charging levels of 11 kW and 22 kW have the highest potential in LV grids. The option of DC fast-charging is only possible in the larger capacity grids, withstanding the parallel charge of one or two vehicles.

Superconducting Wind Turbine Generators

A HTS machine could be a way to address some of the technical barriers offshore wind energy is about to face. Due to the superior power density of HTS machines, this technology could become a milestone on which many, including the wind industry, will rely in the future. The work presented in this thesis is a part of a larger endeavor, the Superwind project that focused on identifying the potentials that HTS machines could offer to the wind industry and addressing some of the challenges in the process. In order to identify these challenges, I have design and constructed a HTS machine experimental setup which is made to serve as precursor, leading towards an optimized HTS machine concept proposed for wind turbines.

In part, the work presented in this thesis will focus on the description of the experimental setup and reasoning behind the choices made during the design. The setup comprises from a HTS synchronous machine where a revolving armature winding spins around an open bath liquid nitrogen cryostat, which contains the HTS coils cooled down to 77 K. A significant part of the thesis is allocated to the description of the setup, particularly the torque transfer element and the compact cryostat design, where a concept with ~20 W of heat transfer is achieved.

Following the setup description, the focus turns to the electromagnetic design consideration of the HTS machine. Particularly, an approach to increase the performance of HTS coils and the influence of the armature reaction to the HTS field winding will be discussed.

Two design strategies are proposed, novel in a machine design, in order to reduce the amount of HTS required in a machine whereby the merits of both have been experimentally verified. The first employs a multiple HTS types in the machine design, since each type of the HTS tape has a specific magnetic characteristic with respect to the critical current. I have showed that the potential for the reduction of HTS conductor can be significant, if the coils are placed strategically, whereby the coils wound with BSCCO performed 40% better depending on the placement in the field winding. The 2G coils were less sensitive to the placement which made them particularly useful for high magnetic field regions in the field winding. The second design approach proposed and tested was to use multiple current supplies which allowed each coil to operate close to its critical current. I have demonstrated that by introducing one additional power supply, an order of 12% higher MMF was generated (or equivalent HTS savings achieved). Increasing in the number of additional power supplies did not show the same potential for HTS reduction.

The implications of an armature reaction impact on the HTS field winding performance were examined and verified throughout a series of Locked Armature experiments. The interaction have been defined in the terms of two (direct and quadrature) axis machine theory (Park transformation), where significant reduction of ~ 20% was observed for the rated armature reaction in the q axis. Building on this observation, a control strategy for the excitation current to improve a partial load efficiency of a HTS machine is proposed.

Thus, this work has shown that a significant savings of a the costly HTS tape could be realized indicating that the HTS machine design can still be optimized towards more competitive alternative to conventional machines. Additionally, by constructing the HTS machine setup we went through most of the issues related to the HTS machine design which we managed to address in rather simple manner using everyday materials and therefore proving that HTS machines are close to commercialization.
AC Losses in Bi2Sr2Ca2Cu3O10+x Tapes and a 3.15-m-Long Single-Phase Cable

The alternating-current losses in superconducting multifilament BiSCCO-2223 tapes and a 3.15-m single-phase test cable were measured at 77 K using an electrical transport method. The cable had an inner diameter of 42 mm; it was composed of a single layer of 31 multifilament tapes and had a critical current of $I_{c} = 4.1 \hbox{kA}$. The measured losses of the tapes were found to be in good agreement with the Norris ellipse (NE) model. The losses of the cable were, for high currents, found to be bounded by the monoblock and independent NE models.
In building the new DTU B.Eng programme [1] one of the pilots on the 4'th semester is the Design-build project course in Electric Energy Systems. In this course, which is the last Designbuild course many of the CDIO Syllabus bullets [2] are addressed starting with problem identification and formulation, experimental inquiry and modelling, finally leading to planning and solution. The goal is to acquire the skills that are needed for an engineer within electric power engineering to analyse a given task, define the necessary steps to solve the task, organize him/her self and others and finally solve the task with success. The concrete work is built up around a miniaturized electric energy system powered by a steam engine. The system mimics an essential sub-section of a real electric power system. The process is realised with a combination of optional lectures, optional exercises, 3 set of self evaluations, weekly supervision and a concluding 3 weeks of intensive lab work. 50+ students are divided in 5 large groups allowing for subsequent sub-organization among 10+ students. The result is well functioning work groups, a robust electric energy system optionally with innovative add-ons such as a solar panel or a cable connection to other similar systems and the acquisition of basic skills within electric power engineering.
Coil Optimization for High Temperature Superconductor Machines
This paper presents topology optimization of HTS racetrack coils for large HTS synchronous machines. The topology optimization is used to acquire optimal coil designs for the excitation system of 3 T HTS machines. Several tapes are evaluated and the optimization results are discussed. The optimization algorithm is formulated to minimize the cost for the coils wound with one type of HTS as well as multiple HTS types. It could also be used to minimize other parameters, e.g. space required for the coils. The results are inherently highly dependent on the HTS properties, which at 20 K seem to be in favor of the 1 G tape. The maximal HTS savings achieved allowing multiple current supplies in the excitation system are investigated and estimated to be in the range of 50% for highly nonlinear J-B dependence HTS tapes.

General information
State: Published
Organisations: Electric Components, Department of Electrical Engineering, Nano-Microstructures in Materials, Materials Research Division, Risø National Laboratory for Sustainable Energy, Dynamical systems, Department of Mathematics
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Scopus rating (2016): CiteScore 1.42 SJR 0.395 SNIP 1.031
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Scopus rating (2015): SJR 0.35 SNIP 0.935 CiteScore 1.27
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Scopus rating (2014): SJR 0.47 SNIP 1.113 CiteScore 0.83
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.431 SNIP 1.171 CiteScore 1.32
ISI indexed (2013): ISI indexed yes
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BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.575 SNIP 1.27 CiteScore 1.11
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.364 SNIP 1.063 CiteScore 1.16
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.468 SNIP 1.073
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.452 SNIP 1.033
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.878 SNIP 0.987
Scopus rating (2007): SJR 0.611 SNIP 1.104
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 0.731 SNIP 0.935
Scopus rating (2005): SJR 0.645 SNIP 0.996
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 0.867 SNIP 0.9
Scopus rating (2003): SJR 0.494 SNIP 1.045
Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 0.849 SNIP 1.024
Scopus rating (2001): SJR 0.523 SNIP 1.336
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Economic Dispatch of Electric Energy Storage with Multi-service Provision
This paper develops a generic optimization model that explores the difficulty met by Electric Energy Storage (EES) systems when economic dispatch for multiple-service provision is requested. Such a model is further used to investigate the economic performance of an EES system which meets the 10-minute balancing requirement and hourly load shifting opportunities in the Western Electricity Coordinating Council (WECC) area for a 2030 load scenario. Piecewise linear equations are used to represent the cost function of varying load. The results show that when EES is economically dispatched, to achieve multiple value streams could result in more saving than to provide single service.

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Authors: You, S. (Intern), Træholt, C. (Intern), Poulsen, B. (Intern)
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Electric Vehicle Requirements for Operation in Smart Grids

Several European projects on smart grids are considering Electric Vehicles (EVs) as active element in future power systems. Both battery-powered vehicles and plug-in hybrid vehicles are expected to interact with the grid, sharing their energy storage capacity. Different coordination concepts for EVs are being investigated, in which vehicles can be intelligently charged or discharged feeding power back to the grid in vehicle-to-grid mode (V2G). To respond to such needs, EVs are required to share their battery internal data as well as respond to external control signals. In this paper, the requirements for the interaction of EVs with the electrical grid are presented. The defined requirements have been implemented on an EV test bed, realized by using real EV components. Charging/V2G tests on the EV test bed have shown that the presented requirements are sufficient to ensure an intelligent coordination of EVs into the electricity grid.

High Temperature Superconductor Machine Prototype

A versatile testing platform for a High Temperature Superconductor (HTS) machine has been constructed. The stationary HTS field winding can carry up to 10 coils and it is operated at a temperature of 77K. The rotating armature is at room temperature. Test results and performance for the HTS field winding comprising four coils wound with two types of HTS tapes are shown and discussed. The field winding produces up to 0.62T in the 10mm air gap which constitutes 78% of the armature design value. Recommendations for the field winding operation are proposed and verified, which resulted in an increase of available magneto-motive force of the field winding up to 25%.
HTS machine laboratory prototype
High Temperature Superconducting (HTS) electrical machines have the potential to offer outstanding technical performance with regards to efficiency and power density. However, the industry needs to address a large number of challenges in the attempt to harvest the full potential of HTS machines. Among others a few stand out, e.g. reliability and efficiency of thermal insulation and cooling systems; optimized torque transfer elements and current leads; commercial availability and competitiveness of HTS material etc. Also, HTS conductors lack standardization due to their rapid development where many of HTS properties are not known and need to be tested with a specific purpose in mind not just for different types of HTS conductors but also for the same type of HTS conductors made by different manufactures. To address some of these challenges, we have constructed a laboratory prototype HTS machine. The machine comprises six stationary HTS field windings wound from both YBCO and BiSCCO tape operated at liquid nitrogen temperature and enclosed in a cryostat, and a three phase armature winding spinning at up to 300 rpm. This design has full functionality of HTS synchronous machines. The design details and experimental results are shown together with discussions about their implication for scaled up HTS machines.

Impacts of electric vehicle charging on distribution networks in Denmark
Electric vehicles (EVs) provide a unique opportunity to reduce carbon dioxide emissions from the transport sector by drawing on renewable resources. As EVs become increasingly popular in the automotive market, the study of its impacts on the low-voltage grid has become increasingly important. The model of EVs is affected by the user, battery characteristics, as well as the environment. Studies are carried out based on the Danish case. A preliminary model on demand is created by integrating the driving pattern and battery charging characteristics. The model is applied to a typical distribution network. Monte Carlo simulation is employed to study the impact of EVs in the presence of wind power considering different penetration levels of EVs, electricity price schemes and seasons. © 2011 State Grid Electric Power Research Institute Press.
Is micro-CHP price controllable under price signal controlled Virtual Power Plants?

As micro-combined heat and power (micro-CHP) systems move towards mass deployment together with other kinds of distributed energy resources (DER), an increasing emphasis has been placed on how to coordinate such a large diversified DER portfolio in an efficient way by the Virtual Power Plant (VPP) like aggregators. Compared to the centralized direct control scheme, a decentralized control scheme “control-by-price” is proposed for the VPP operation. The corresponding scheme has advantages in scalability, transparency and simplicity. In this context, a short term economic analysis is conducted for three different micro-CHP systems to investigate the feasibility of being controlled by price. Such analysis is relevant for both controller designs for micro-CHP systems and VPP related operations. The results indicate that controlling the micro-CHP systems by price is feasible but could result in jumpy responses.
Minimising the Usage of Superconducting Tape in Electrical Machine Applications

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Organisations: Department of Electrical Engineering, Electric Components, Wind Energy Systems, Department of Wind Energy
Authors: Jensen, B. B. (Intern), Mijatovic, N. (Intern), Abrahamsen, A. B. (Intern), Træholt, C. (Intern)
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Power quality issues into a Danish low-voltage grid with electric vehicles
An increased interest on electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs) is dealing with their introduction into low voltage (LV) distribution grids. Lately, analysis on power quality issues has received attention when considering EVs as additional load. The charging of EVs is expected without a centralized coordination in the first years, therefore a study on voltage variations and loading of LV grids is needed to estimate the immediate impact by EVs. In this work, the modeling and simulation of a Danish residential LV grid is conducted considering the two scenarios of dumb charging and overnight charging. The effect of different shares of EVs on voltage variations and transformer loading is assessed and analyzed. Results have shown that if single-phase, 16 A charging is employed, the actual LV grid would withstand the contingency of up to 30-40% of EVs charging overnight.

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Authors: Marra, F. (Intern), Jensen, M. M. (Ekstern), Garcia-Valle, R. (Intern), Træholt, C. (Intern), Larsen, E. (Intern)
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Superconducting Machines at the Technical University of Denmark
Two high temperature superconducting (HTS) machine prototypes constructed at the Technical University of Denmark are presented. The construction process is presented and the excellent agreement between simulation results and experimental results are presented for one of the prototypes.

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Organisations: Department of Electrical Engineering, Electric Components, Risø National Laboratory for Sustainable Energy, Materials Research Division, Nano-Microstructures in Materials
Authors: Jensen, B. B. (Intern), Abrahamsen, A. B. (Intern), Mijatovic, N. (Intern), Træholt, C. (Intern)
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Main Research Area: Technical/natural sciences
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Towards Faster FEM Simulation of Thin Film Superconductors: A Multiscale Approach

This work presents a method to simulate the electromagnetic properties of superconductors with high aspect ratio such as the commercially available second generation superconducting YBCO tapes. The method is based on a multiscale representation for both thickness and width of the superconducting domains. A couple of test cases were successfully simulated and further investigations were made by means of structured (mapped) meshes. Here, large aspect ratio elements were used to simulate thin material layers with a reduced number of elements. Hence, more complex geometries can be studied at considerable lower computational time. Several test cases were simulated including transport current, externally applied magnetic field and a combination of both. The results are in good agreement with recently published numerical simulations. The computational time to solve the present multiscale approach in 2D is estimated as two orders of magnitude faster than other 2D methods.
Developing Virtual Power Plant for Optimized Distributed Energy Resources Operation and Integration

Distributed Energy Resources (DER) are small-scale power generation and storage technologies, (typically in the range of a few kWe to tens of kWe) located close to the customer side. They are right now under heavy development and have a great market potential in the near future. However, these sources are usually deployed in way of “fit and forget” which to a great extent confines their value and presents challenges in relation to:

- Optimized DER operation related to time varying onsite demand requirements, ambient conditions and electricity prices, etc.
- Coordinated control of many small units in the electric power system
- Efficient electricity market participation to benefit both power system operation and DER owners

To address these issues, an innovative concept Virtual Power Plant (VPP) is investigated in this PhD study. Based on a comprehensive overview of the state of the art of VPP, the Market-Based VPP (MBVPP) concept is proposed. The function-based MBVPP provides a generic and flexible solution for the DER integration by connecting the DER to the bulk power system operation via market participation.

Two schemes for managing the DER generation and trading portfolios, direct control and price signal control have been discussed and simulated. Due to their prevalence and controllability, the μCHP systems are modeled to represent the general DER technology in the corresponding studies. For the direct controlled VPP, all the μCHP units are optimally controlled by the VPP operator based on forecasted market and demand information. For the proposed price signal scheme, an Artificial Neural Network (ANN) is developed to characterize and estimate the price responsiveness of a μCHP group. It is found that although the prognosis result is relatively good, the price signal controlled scheme is still challenged by many uncertainties which reside in the nature of price signal control such as jumpy response. To demonstrate the feasibility of the VPP, a prototyped VPP with two Dachs μCHP systems is set up in the laboratory as a proof of concept. It has shown that, on the premise of an advanced Information and Communication Technology (ICT) infrastructure, the VPP represents a feasible solution to be implemented.

General information

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Organisations: Electric Components, Department of Electrical Engineering, Software Engineering, Department of Informatics and Mathematical Modeling
Authors: You, S. (Intern), Træholt, C. (Intern), Poulsen, B. (Intern)
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AC loss in superconducting wires operating in a wind turbine like generator

We have manufactured a small circular superconducting coil impregnated with epoxy fibreglass. The coil was wound from a Bi-2223/Ag superconducting wire and it was tested in liquid nitrogen at 77 K. Current-voltage characteristic and the AC losses of the coil were measured and compared with the measurements on the original tape. The AC losses of the coil are approximately 10 times higher than the losses of the tape and they have been measured in two different experimental arrangements, one with directly connected and the other with transformer coupled power supply. Measurements in both arrangements resulted in the same AC loss characteristic. This work was done as a part of the Superwind project which aims to build a series of test coils and a spinning model of a generator to investigate AC loss and stability of the coils in wind turbine like conditions.
Average Behavior of Battery - Electric Vehicles for Distributed Energy System Studies
The increase of focus on electric vehicles (EVs) as distributed energy resources calls for new concepts of aggregated models of batteries. Despite the developed battery models for EVs applications, when looking at energy storage scenarios using EVs, both geographical-temporal aspects and battery use conditions cannot be neglected for a proper estimation of available fleet energy. In this paper we describe an average behavior of battery-EVs. Main points of this concept include the definition of the energy window and lifetime of the batteries, in relation to existing models and battery use conditions.

The obtained results show that EV fleets are non-linear time-variant systems which however can be described with good approximation taking into account a number of variables such as number of cycles, temperature, depth-of-discharge and current rates.

Coil Optimization for HTS Machines
An optimization approach of HTS coils in HTS synchronous machines (SM) is presented. The optimization is aimed at high power SM suitable for direct driven wind turbines applications. The optimization process was applied to a general radial flux machine with a peak air gap flux density of ~3T. The proposed coil design is optimized with respect to minimizing the perpendicular field while still maximizing the amplitude of fundamental space harmonic. This guarantees the lowest HTS loss density and best utilization of expensive HTS material in the field winding of the SM. Additionally, accounting for different tape parameters $I_{ci}$, $n_i$ and $C_i$, where $I_{ci}$, $n_i$ and $C_i$ are critical current, $n$ - value and price of the ith tape respectively and $i=1, 2, 3...$, further optimization with respect to cost vs. HTS losses has been performed. Allowing for different types of HTS tapes in the coils, a guidance to which tape is suitable for which coil segment is presented. Thus, the performed study gives valuable input for the coil design of HTS machines ensuring optimal usage of HTS tapes.
Driving Pattern Analysis for Electric Vehicle (EV) Grid Integration Study

In order to facilitate the integration of electric vehicles (EVs) into the Danish power system, the driving data in Denmark were analyzed to extract the information of driving distances and driving time periods which were used to represent the driving requirements and the EV unavailability. The Danish National Transport Survey data (TU data) were used to implement the driving data analysis. The average, minimum and maximum driving distances were obtained for weekdays, weekends and holidays to illustrate the EV users’ driving requirements in different days. The EV availability data were obtained from the driving time periods to show how many cars are available for charging and discharging in each time period. The obtained EV availability data are in one hour time periods and one quarter time periods for different study purposes. The EV availability data of one hour time period are to be used for optimal EV charging study in energy power market. The EV availability data of quarter time periods are to be used to investigate the possibility of utilizing EVs for providing regulation power. The statistical analysis software, SAS, was used to carry out the driving data analysis.

Electric Vehicle Fleet Integration in the Danish EDISON Project: A Virtual Power Plant on the Island of Bornholm

The Danish EDISON project has been launched to investigate how a large fleet of electric vehicles (EVs) can be integrated in a way that supports the electric grid while benefitting both the individual car owners and society as a whole through reductions in CO2 emissions. The consortium partners include energy companies, technology suppliers and research laboratories and institutes. The aim is to perform a thorough investigation of the challenges and opportunities of EVs and then to deliver a technical platform that can be demonstrated on the Danish island of Bornholm. To reach this goal, a vast amount of research is done in various areas of EV technology by the partners. This paper will focus on the ICT-based distributed software integration, which plays a major role for the success of EDISON. Key solution technologies and standards that will accommodate communication and optimize the coordination of EVs will be described as well as the
Facilitating a generic communication interface to distributed energy resources: Mapping IEC 61850 to RESTful services

As the power system evolves into a smarter and more flexible state, so must the communication technologies that support it. A key requirement for facilitating the distributed production of future grids is that communication and information are standardized to ensure interoperability. The IEC 61850 standard, which was originally aimed at substation automation, has been expanded to cover the monitoring and control of Distributed Energy Resources (DERs). By having a consistent and well-defined data model the standard enables a DER aggregator, such as a Virtual Power Plant (VPP), in communicating with a broad array of DERs. If the data model of IEC 61850 is combined with a set of contemporary web protocols, it can result in a major shift in how DERs can be accessed and coordinated. This paper describes how IEC 61850 can benefit from the REpresentational State Transfer (REST) service concept and how a server using these technologies can be used to interface with DERs as diverse as Electric Vehicles (EVs) and micro Combined Heat and Power (μCHP) units.
Modeling and Testing of EVs - Preliminary Study and Laboratory Development

Electric vehicles (EVs) are expected to play a key role in the future energy management system to stabilize both supply and consumption with the presence of high penetration of renewable generation. A reasonably accurate model of battery is a key element for the study of EVs behavior and the grid impact at different geographical areas, as well as driving and charging patterns. Electric circuit model is deployed in this work to represent the electrical properties of a lithium-ion battery. This paper reports the preliminary modeling and validation work based on manufacturer data sheet and realistic tests, followed by the suggestions towards a feasible battery model for further studies.

Superconducting generators for wind turbines: design considerations

The harmonic content of high temperature superconductors (HTS) field winding in air-core high temperature superconducting synchronous machine (HTS SM) has been addressed in order to investigate tendency of HTS SM towards mechanical oscillation and additional loss caused by higher flux harmonic. Both analytical expressions for flux distribution and current sheet distribution have been derived and analyzed. The two main contributors to the AC loss of HTS rotor winding are also identified and their influence addressed on general level.

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Web of Science (2017): Indexed yes
We have examined the potential of 10 MW superconducting direct drive generators to enter the European offshore wind power market and estimated that the production of about 1200 superconducting turbines until 2030 would correspond to 10% of the EU offshore market. The expected properties of future offshore turbines of 8 and 10 MW have been determined from an up-scaling of an existing 5 MW turbine and the necessary properties of the superconducting drive train are discussed. We have found that the absence of the gear box is the main benefit and the reduced weight and size is secondary. However, the main challenge of the superconducting direct drive technology is to prove that the reliability is superior to the alternative drive trains based on gearboxs or permanent magnets. A strategy of successive testing of superconducting direct drive trains in real wind turbines of 10 kW, 100 kW, 1 MW and 10 MW is suggested to secure the accumulation of reliability experience. Finally, the quantities of high temperature superconducting tape needed for a 10 kW and an extreme high field 10 MW generator are found to be 7.5 km and 1500 km, respectively. A more realistic estimate is 200–300 km of tape per 10 MW generator and it is concluded that the present production capacity of coated conductors must be increased by a factor of 36 by 2020, resulting in a ten times lower price of the tape in order to reach a realistic price level for the superconducting drive train.

Superconducting wind turbine generators

We have examined the potential of 10 MW superconducting direct drive generators to enter the European offshore wind power market and estimated that the production of about 1200 superconducting turbines until 2030 would correspond to 10% of the EU offshore market. The expected properties of future offshore turbines of 8 and 10 MW have been determined from an up-scaling of an existing 5 MW turbine and the necessary properties of the superconducting drive train are discussed. We have found that the absence of the gear box is the main benefit and the reduced weight and size is secondary. However, the main challenge of the superconducting direct drive technology is to prove that the reliability is superior to the alternative drive trains based on gearboxs or permanent magnets. A strategy of successive testing of superconducting direct drive trains in real wind turbines of 10 kW, 100 kW, 1 MW and 10 MW is suggested to secure the accumulation of reliability experience. Finally, the quantities of high temperature superconducting tape needed for a 10 kW and an extreme high field 10 MW generator are found to be 7.5 km and 1500 km, respectively. A more realistic estimate is 200–300 km of tape per 10 MW generator and it is concluded that the present production capacity of coated conductors must be increased by a factor of 36 by 2020, resulting in a ten times lower price of the tape in order to reach a realistic price level for the superconducting drive train.

General information

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Superconducting wind turbines

General information
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Towards faster FEM simulation of thin film superconductors

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A Market-Based Virtual Power Plant
The fast growing penetration of Distributed Energy Resources (DER) and the continuing trend towards a more liberalized electricity market requires more efficient energy management strategies to handle both emerging technical and economic issues. In this paper, a market-based Virtual Power Plant (MBVPP) model is proposed which provides individual DER units the accesses to current electricity markets. General bidding scenario and price signal scenario as two optional operation scenarios are operated by one MBVPP. In the end, a use case of a MBVPP with micro Combined Heat and Power (µCHP) systems demonstrates the potential benefits and operation scenarios of the MBVPP model.
A study on electricity export capability of the μCHP system with spot price

When a number of μCHP systems are aggregated as a virtual power plant (VPP), they will be able to participate in the electricity wholesale market with no discrimination compared to conventional large power plants. Hence, this paper investigates the electricity export capability of the μCHP system when the electricity buyback price is given at a value equalizing the dynamic spot price. A μCHP system is modeled with optimized generation, and the marginal price of electricity export for such system is explained. A sensitivity analysis of several key factors, e.g. fuel price, heat to power ratio of the μCHP unit, which influence the export capability of μCHP system, is firstly carried out in the intraday case study, followed by the annual case study which explores the annual system performance. The results show that the electricity export capability of a μCHP system is closely related to its technical parameters, the associated energy price during the trade, as well as the demand profile. Furthermore, the μCHP system running under fluctuating spot price is likely to gain more profit than that running under a fixed electricity export price.
Design study of 10 kW superconducting generator for wind turbine applications

We have performed a design study of a 10 kW superconducting slow rotating generator suitable for demonstration in a small scale wind turbine, where the drive train only consists of the turbine blades connected directly to the generator. The flux density in the superconducting rotor is chosen as $B = 1$ Tesla to be similar to the performance of permanent magnets and to represent a layout, which can be scaled up in future off-shore wind turbines. The proposed generator is a 8 pole synchronous machine based on race-track coils of high temperature superconducting tapes and an air cored copper stator enclosed in an iron shield.
Generic Virtual Power Plants: Management of Distributed Energy Resources under Liberalized Electricity Market

The emergence of Virtual Power Plant (VPP) can be attributed to the major boost of distributed energy resources (DER), which satisfies the changing needs of modern society on energy industry. Based on this concept, DER units disregarding the differences in each individual technology are loosely aggregated with a unique interface to the external grid and energy...
market. This paper gives a broad overview of state-of-the-art VPP concepts and proposes a detailed generic VPP (GVPP) model running in liberalized electricity market environment. An attempt is made to provide an outline of the main functions that are necessary for the efficient operation of GVPP. By applying with the function-based design (FBD) method, GVPP developers with different system requirements are able to get the most flexibility out of the GVPP model. This is demonstrated in a case study wherein different GVPP scenarios are employed. Tools and methods associated with the functions are also briefly presented to further facilitate the development of GVPP.

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Authors: Østergaard, J. (Intern), Holbøll, J. (Intern), Nielsen, A. H. (Intern), Garcia-Valle, R. (Intern), Nyeng, P. (Intern), Træholt, C. (Intern)
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Superconducting generators for wind turbines

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Materials and systems for energy storage, Wind energy
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Using Service Oriented Architecture in a Generic Virtual Power Plant

The purpose of this paper is to find and describe a suitable software framework that can be used to help implement the concept of a Generic Virtual Power Plant in the future power system. The Generic Virtual Power Plant concept, along with the utilization of distributed energy resources, has many interesting properties that can influence the future shape of power markets. The concept holds many promises including cheaper power to the consumer, a more flexible and responsive power production and the support of a more environment-friendly development. In order to realize a software solution supporting the Generic Virtual Power Plant, an array of different software design principles, patterns and architectures must be applied. Especially Service Oriented Architecture (SOA) can aid in implementing the Generic Virtual Power Plant.
supporting the generic virtual power plant, an array of different software design principles, patterns and architectures must be applied. Especially Service Oriented Architecture (SOA) can aid in implementing the generic virtual power plant. An analysis of the Nordic power market has been carried out in order to identify potential issues and barriers, henceforth mentioned as challenges, connected with the introduction of the generic virtual power plant concept. In this paper, three use case scenarios will show how each of these challenges can be overcome by the proposed solution framework. The use case scenarios will be tested by a prototype that has been developed as proof of concept.

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FEM: a tool for designing a superconducting generator for a wind turbine

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Authors: Mijatovic, N. (Intern), Sørensen, M. P. (Intern), Abrahamsen, A. B. (Intern), Træholt, C. (Intern), Pedersen, N. F. (Intern)
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Operation experiences with a 30 kV/100 MVA high temperature superconducting cable system
A superconducting cable based on Bi-2223 tape technology has been developed, installed and operated in the public network of Copenhagen Energy in a two-year period between May 2001 and May 2003. This paper gives a brief overview of the system and analyses some of the operation experiences. The aim of this demonstration project is to gain experience with HTS cables under realistic conditions in a live distribution network. Approximately 50 000 utility customers have their electric power supplied through the HTS cable. The cable system has delivered 226 GW h of energy and reached a maximum operating current of 1157 A. The operation experiences include over-currents of 6 kA due to faults on peripheral lines, commissioning, servicing and failure responses on the cooling system, continuous 24 h, 7 day per week monitoring and performance of the alarm system. The implications of these experiences for the future applications of HTS
cable systems are analysed.

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Scopus rating (2016): CiteScore 2.07 SJR 0.849 SNIP 1.261  
BFI (2015): BFI-level 1  
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Scopus rating (2014): SJR 1.054 SNIP 1.178 CiteScore 1.71  
Web of Science (2014): Indexed yes  
BFI (2013): BFI-level 1  
Scopus rating (2013): SJR 0.873 SNIP 1.144 CiteScore 1.78  
ISI indexed (2013): ISI indexed yes  
Web of Science (2013): Indexed yes  
BFI (2012): BFI-level 1  
Scopus rating (2012): SJR 1.243 SNIP 1.089 CiteScore 1.66  
ISI indexed (2012): ISI indexed yes  
Web of Science (2012): Indexed yes  
BFI (2011): BFI-level 1  
Scopus rating (2011): SJR 1.403 SNIP 1.352 CiteScore 2.4  
ISI indexed (2011): ISI indexed yes  
Web of Science (2011): Indexed yes  
BFI (2010): BFI-level 1  
Scopus rating (2010): SJR 1.453 SNIP 1.278  
Web of Science (2010): Indexed yes  
BFI (2009): BFI-level 1  
Scopus rating (2009): SJR 1.266 SNIP 1.426  
Web of Science (2009): Indexed yes  
BFI (2008): BFI-level 1  
Scopus rating (2008): SJR 1.9 SNIP 1.397  
Web of Science (2008): Indexed yes  
Scopus rating (2007): SJR 1.365 SNIP 1.48  
Web of Science (2007): Indexed yes  
Scopus rating (2006): SJR 1.409 SNIP 1  
Web of Science (2006): Indexed yes  
Scopus rating (2005): SJR 1.382 SNIP 1.164  
Web of Science (2005): Indexed yes
A New Concept for Superconducting DC Transmission from a Wind Farm

Projects with large offshore wind farms (up to 500 MW) are in progress. Connecting the parks to the power grid with conventional AC transmission technique is difficult due to non-controllable power flow and voltage stability problems. A new concept for connecting remotely located wind farms is suggested and described. The concept is based on combining superconducting DC power transmission and cooled power electronic.

General information
State: Published
Authors: Østergaard, J. (Intern), Tønnesen, O. (Intern), Pedersen, J. K. (Intern), Nielsen, A. H. (Intern), Træholt, C. (Intern)
Pages: 1560–1563
Publication date: 2002
Main Research Area: Technical/natural sciences

Publication information
Journal: Physica C: Superconductivity and its Applications
Volume: 372-376
Issue number: 3
ISSN (Print): 0921-4534
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.14 SJR 0.575 SNIP 0.924
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.446 SNIP 0.888 CiteScore 0.99
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.497 SNIP 0.83 CiteScore 0.85
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.439 SNIP 0.7 CiteScore 0.79
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.55 SNIP 0.621 CiteScore 0.79
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
A new concept for superconducting DC transmission from a wind turbine park

General information
State: Published
Organisations: Electric Power Engineering, Department of Electrical Engineering, Department of Electric Power Engineering, Centre for Electric Technology
Authors: Østergaard, J. (Intern), Tønnesen, O. (Intern), Pedersen, J. K. (Intern), Nielsen, A. H. (Intern), Træholt, C. (Intern)
Pages: 1560-1563
Publication date: 2002
Main Research Area: Technical/natural sciences

Publication information
Journal: Physica C
Volume: 372
ISSN (Print): 0921-4534
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.14 SJR 0.575 SNIP 0.924
First operation experiences from a 30 kV 104 MVA HTS power cable installed in a utility substation

An HTS cable with a voltage rating of 30 kV and a power rating of 104 MVA, has been installed and operated in the electric grid of Copenhagen Energy in the spring of 2001. This article describes the development phases, the system specifications, and the first experiences of operation under realistic conditions in the substation of Amager (AMK). Approximately 50 000 private and business customers are supplied from this cable. The load can be adjusted from 20% to 100% of the power supplied and the number of branches connected can be altered. This and other early HTS power installations are expected to act as ice-breakers for the HTS technology.
Calorimetric measurements of losses in HTS cables

A calorimetric test rig is used to investigate various loss components in a 10 m long superconducting cable model. A calorimetric technique, based on thermocouple measurements, is used to measure the losses of the 10 m long superconducting cable model. The current dependent losses are also measured electrically and compared with the losses obtained with the calorimetric method. The results obtained by the two methods are consistent. Based on an I² (current) fitting procedure, the loss, caused by the eddy current generated in the stainless steel cryostat housing, and the hysteresis loss generated in the conductor can be separated. From this result, it appears that the two contributions are roughly equal in size.

General information
State: Published
Organisations: Electric Power Engineering, Department of Electrical Engineering, Department of Electric Power Engineering, Electric Components
Pages: 1777-1780
Publication date: 2001
Main Research Area: Technical/natural sciences

Publication information
Journal: IEEE Transactions on Applied Superconductivity
Volume: 11
Issue number: 1
ISSN (Print): 1051-8223
Ratings:
BFI (2018): BFI-level 1
Connection for transfer of Liquid Nitrogen from High Voltage to ground potential

In order to operate a superconducting cable conductor it must be kept at a cryogenic temperature (e.g. using liquid nitrogen). The superconducting cable conductor is at high voltage and the cooling equipment is kept at ground potential. This requires a thermally insulating connection that is also electrically insulating. Here, the design, construction and test results of such a device are described. It consists of 2 coaxial glass fibre reinforced polymer (GFRP) tubes with insulating foam between them. Foams are generally not recommended for use in high electrical fields, due to low electrical breakdown strength. However, samples of Expancel® (polymer foam) have recently proved to withstand large electrical fields at room temperature as well as at cryogenic temperatures. In this work, two prototype devices have been tested with respect to the partial discharge inception voltage, thermal insulation properties and withstand towards high-pressure liquid nitrogen. The length per joint is approximately 900 mm, including a Johnston coupling. The joints are tested in a closed liquid nitrogen circuit, with a pressure of up to 10 bars. The rated voltage of the cable system is 36 kV (phase-phase).

General information
State: Published
Authors: Rasmussen, C. N. (Intern), Hansen, F. (Ekstern), Willén, D. (Ekstern), Rasmussen, C. (Ekstern), Træholt, C. (Intern)
Publication date: 2001

Host publication information
Title of host publication: Proceedings of the 2001 Nordic Insulation Symposium
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 279774
Publication: Research - peer-review › Article in proceedings – Annual report year: 2001

Overcurrent experiments on HTS tape and cable conductor

Overcurrents in the power grid can have a magnitude of up to 20 times or higher than the rated current. This may cause problems and permanent damage to electrical equipment in the grid. High temperature superconducting (HTS) tapes are known to be sensitive to currents much larger than their critical current. In this light, it is important to investigate the response of HTS tapes and cable conductors to overcurrents several times the critical current. A number of experiments have been performed on HTS tapes and cable conductors, with currents up to 20 times the critical current. During overcurrent experiments, the voltage, and the temperature were measured as functions of time in order to investigate the dynamic behavior of the HTS tape and cable conductor. After each experiment, damage to the superconductors was assessed by measuring the critical current. Preliminary results show that within seconds an HTS tape (critical current=17 A) heats above room temperature with an overcurrent larger than 140 A. Similar overcurrent experiments showed that a HTS cable conductor could sustain damage with overcurrents exceeding 10 times the critical current of the cable conductor.

General information
State: Published
Organisations: Electric Power Engineering, Department of Electrical Engineering, Electric Components, Department of Electric Power Engineering
Pages: 1781-1784
Publication date: 2001
Main Research Area: Technical/natural sciences

Publication information
Journal: I E E E Transactions on Applied Superconductivity
Volume: 11
Issue number: 1
ISSN (Print): 1051-8223
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed yes
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<td>1999</td>
<td>1</td>
<td>1.073 SJR 2.106</td>
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**Bibliographical note**

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Source: orbit

Source-ID: 188718

Publication: Research - peer-review › Journal article – Annual report year: 2001
Test results of full-scale high temperature superconductors cable models destined for a 36 kV, 2 kA(rms) utility demonstration

Power cable systems using high temperature superconductors (HTS) are nearing technical feasibility. This presentation summarises the advancements and status of a project aimed at demonstrating a 36 kV, 2 kA(rms) AC cable system by installing a 30 m long full-scale functional model in a power utility. The expected benefits of such a system include reduced energy loss and increased power rating in a small cross-section. Electrical losses below 1 W/m/phase at 2 kA(rms) have been obtained in these conductors. The cable system consists of conventional electrical terminations in conjunction with thermal terminations, an HTS cable conductor including a flexible thermal insulation, a conventional room temperature dielectric, and a closed-loop circulating cooling system maintaining the temperature between 68 and 78 K. Critical issues before the commercialisation of this technology are the improvement of the thermal insulation, and the reduction of costs. 

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Nominal current test performance of 2 kA -class high Tc superconducting cable conductor and its implication for cooling systems for utility cables

General information
State: Published
Organisations: Department of Electric Power Engineering
Pages: 1501-1506
Publication date: 2000
Main Research Area: Technical/natural sciences

Publication information
Journal: Advances in Cryogenic Engineering
Volume: 45B
ISSN (Print): 0065-2782
Ratings:
ISI indexed (2013): ISI indexed no
ISI indexed (2012): ISI indexed no
ISI indexed (2011): ISI indexed no
Scopus rating (2001): SJR 0.111
Scopus rating (2000): SJR 0.216
Web of Science (2000): Indexed yes
Scopus rating (1999): SJR 0.111
Original language: English
Links:
Source: orbit
Source-ID: 177651
Publication: Research - peer-review » Journal article – Annual report year: 2000
SC Power leads and cables - Nominal Current Test Performance of 2 kA-Class High-Tc Superconducting Cable Conductors and Its Implications for Cooling Systems for Utility Cables

The current carrying performance of 3-10 m long superconducting cable conductor models has been evaluated. A reduced energy loss compared to conventional cables can be obtained using high-Tc superconducting materials due to the limited resistive and ac hysteresis losses in some conductor configurations. The conductors are characterised under dc and ac conditions. The current and voltage is recorded during the tests in order to determine the impedances and the losses of the cable models. Using a phase-sensitive measurement with two lock-in amplifiers, small losses can be accurately measured at high currents. The critical currents of these conductors are in the range of 1-3 kA, and ac losses smaller than 1 W/m are measured at 2 kArms. AC currents with peak values exceeding the dc critical currents are applied. Increased losses, in excess of the expected magnetization losses are observed when individual layers in the cables saturate. The loss-contributions from other components of the cable system are discussed, and the implications for the cooling apparatus for superconducting utility cables are determined.

General information
State: Published
Organisations: Department of Electric Power Engineering, Electric Power Engineering, Department of Electrical Engineering
Pages: 1501-1507
Publication date: 2000
Conference: CEC/ICMC Conference, Montreal, Canada, 12/07/1999 - 12/07/1999
Main Research Area: Technical/natural sciences

Publication information
Journal: Advances in Cryogenic Engineering (Part A & B)
Volume: 45
Issue number: B
ISSN (Print): 0065-2482
Ratings:
ISI indexed (2013): ISI indexed no
ISI indexed (2012): ISI indexed no
ISI indexed (2011): ISI indexed no
Scopus rating (2001): SJR 0.111
Scopus rating (2000): SJR 0.216
Web of Science (2000): Indexed yes
Scopus rating (1999): SJR 0.111
Original language: English
Source: orbit
Source-ID: 173985
Publication: Research - peer-review › Journal article – Annual report year: 2000

Studies of High temperature Superconductors: AC loss in superconducting power cables

General information
State: Published
Organisations: Department of Electric Power Engineering, Department of Electrical Engineering, DEFU a.m.b.a.
Authors: Olsen, S. K. (Intern), Træholt, C. (Intern), Kyhle, A. (Intern), Rasmussen, C. (Intern), Tønnesen, O. (Intern), Jacob, Ø. (Ekstern)
Number of pages: 39
Publication date: 2000

Publication information
Publisher: A.V. Narlikar
Original language: English
Series: Studies of High Temperature Superconductors
Volume: 33
ISSN: 1050-3943
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 173986
Test of a cryogenic set-up for a 10 meter long liquid nitrogen cooled superconducting power cable

General information
State: Published
Organisations: Department of Electric Power Engineering
Publication date: 2000
Conference: CEC/ICMC Conference, Montreal, Canada, 12/07/1999 - 12/07/1999
Main Research Area: Technical/natural sciences

Publication information
Journal: Advances in Cryogenic Engineering
Volume: 45

Alternating current losses of a 10 metre long low loss superconducting cable conductor determined from phase sensitive measurements
The ac loss of a superconducting cable conductor carrying an ac current is small. Therefore the ratio between the inductive (out-of-phase) and the resistive (in-phase) voltages over the conductor is correspondingly high. In vectorial representations this results in phase angles between the current and the voltage over the cable close to 90 degrees. This has the effect that the loss cannot be derived directly using most commercial lock-in amplifiers due to their limited absolute accuracy. However, by using two lock-in amplifiers and an appropriate correction scheme the high relative accuracy of such lock-in amplifiers can be exploited. In this paper we present the results from ac-loss measurements on a low loss 10 metre long high temperature superconducting cable conductor using such a correction scheme. Measurements were carried out with and without a compensation circuit that could reduce the inductive voltage. The 1 μV cm(-1) critical current of the conductor was 3240 A at 77 K. At an rms current of 2 kA (50 Hz) the ac loss was derived to be 0.6 +/- 0.15 W m(-1). This is, to the best of our knowledge, the lowest value of ac loss of a high temperature superconducting cable conductor reported so far at these high currents.

General information
State: Published
Organisations: Department of Electric Power Engineering
Authors: Olsen, S. K. (Intern), Kühle (fratrådt), A. V. D. A. (Ekstern), Træholt, C. (Intern), Rasmussen, C. (Intern), Tønnesen, O. (Intern)
Pages: 360-365
Publication date: 1999
Main Research Area: Technical/natural sciences

Publication information
Journal: Superconductor Science & Technology
Volume: 12
Issue number: 6
ISSN (Print): 0953-2048

Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
Loss and Inductance Investigation in Superconducting Cable Conductors
Measuring ac-loss in high temperature superconducting cable-conductors using four probe methods

General information
State: Published
Organisations: Department of Electric Power Engineering, NKT Research & Innovation A/S
Pages: 1169-1172
Publication date: 1999
Main Research Area: Technical/natural sciences
Publication information
Journal: IEEE Transactions on Applied Superconductivity
Volume: 9
Issue number: 2
ISSN (Print): 1051-8223
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.42 SJR 0.395 SNIP 1.031
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.35 SNIP 0.935 CiteScore 1.27
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.47 SNIP 1.113 CiteScore 0.83
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.431 SNIP 1.171 CiteScore 1.32
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.575 SNIP 1.27 CiteScore 1.11
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.364 SNIP 1.063 CiteScore 1.16
ISI indexed (2011): ISI indexed yes
The Electrical Aspects of the choice of Former in a High T-c Superconducting Power Cable

Centrally located in a superconducting power cable the former supplies a rigid means onto which to wind the superconducting tapes and enables a continuous supply of cooling power via a flow of liquid cryogen through it. Therefore, the choice of former has a broad impact on the construction and design of a cable. The diameter of the former determines the overall diameter of the total cable, influences the heat loss to the ambient and enters into the total AC-losses. Depending on whether the former is made of a good or poor electrical conductor eddy currents in the former itself may also contribute significantly to the AC-loss of the cable; the choice between an open and a closed former determines how and where the pressure load (pressurized coolant) has to be accommodated. In this work the electrical impact of the choice of material and diameter of the former on the AC-loss of a cable conductor is addressed.

General information
State: Published
Organisations: Department of Electric Power Engineering
Pages: 766-769
Publication date: 1999
Main Research Area: Technical/natural sciences

Publication information
Journal: IEEE Transactions on Applied Superconductivity
Volume: 9
Issue number: 2
ISSN (Print): 1051-8223
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
AC losses in circular arrangements of parallel superconducting tapes

General information
State: Published
Organisations: Department of Electric Power Engineering
Pages: 192-196
Measurement of AC losses in different former materials

A high temperature superconducting cable may be based on a centrally located cylindrical support, a so-called former. If electrically conductive, the former can contribute to the AC losses through eddy current losses caused by unbalanced axial and tangential magnetic fields. With these measurements we aim at investigating the eddy current losses of commonly used former materials. A one layer cable conductor was wound on a glass fibre reinforced polymer (GRFP) former. By inserting a variety of materials into this, it was possible to measure the eddy current losses of each of the former candidates separately; for example copper tubes, stainless steel braid, copper braid, corrugated stainless steel tubes, etc. The measured data are compared with the predictions of a theoretical model. Our results show that in most cases, the losses induced by eddy currents in the former are negligible. However, for materials with a low resistivity the eddy current losses may become significant, e.g. for high purity Cu or Al.

General information
State: Published
Organisations: Department of Electric Power Engineering
Pages: 267-271
Publication date: 1998
Conference: The International Cryogenic Materials Conference ICMC98, Topical Conference on AC Loss and Stability of Low- and High Tc Superconductors, University of Twente, Enchede, 01/01/1998
Main Research Area: Technical/natural sciences

Publication information
Journal: Physica C: Superconductivity and its Applications
Volume: 310
Issue number: 1-4
ISSN (Print): 0921-4534
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.14 SJR 0.575 SNIP 0.924
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.446 SNIP 0.888 CiteScore 0.99
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.497 SNIP 0.83 CiteScore 0.85
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.439 SNIP 0.7 CiteScore 0.79
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.55 SNIP 0.621 CiteScore 0.79
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
Measuring ac losses in superconducting cables using a resonant circuit: Resonant current experiment (RESCUE).

A simple way to obtain true ac losses with a resonant circuit containing a superconductor, using the decay of the circuit current, is described. For the measurement a capacitor is short circuited with a superconducting cable. Energy in the circuit is provided by either charging up the capacitors with a certain voltage, or letting a dc flow in the superconductor. When the oscillations are started—either by opening a switch in case a dc is flowing or by closing a switch to connect the charged capacitors with the superconductor—the current (via a Rogowski coil) or the voltage on the capacitor can be recorded using, for example, a digital oscilloscope. The amplitude decay of the periodic voltage or current accurately reflects the power loss in the system. It consists of two components—an ohmic purely exponential one (from leads, contacts, etc.), and a nonexponential component originating from the superconductor. The method has been successfully applied for the measurement of the ac loss in a 1 m long superconducting cable model.

General information
State: Published
Organisations: Department of Electric Power Engineering
Pages: 1306-1310
Publication date: 1998
Main Research Area: Technical/natural sciences

Publication information
Journal: Superconductor Science & Technology
Volume: 11
Issue number: 11
ISSN (Print): 0953-2048
Across Continents Electric Vehicle Services

ACES intends to holistically investigate technical and economic system benefits and impacts by large scale electric vehicles integration in Bornholm, augmented by real usage patterns, grid data and field testing for across continents replicability.

A full scale penetration scenario of EVs in Bornholm will be simulated in order to assess how new aggregating functionality can support both technically and economically the successful integration of electric vehicles into the energy system. It will also initiate a small scale pilot project involving up to 50 publicly and privately owned Nissan vehicles and V2G chargers for proving that EVs can be used for effectively balance the system.

The analysis, although focused on a Danish context, is enhanced also by comparing existing electricity market services in UK and in Japan, taking advantage by the strong collaboration established with the Japanese and UK based research centers of Nissan.

Department of Electrical Engineering
Center for Electric Power and Energy
Energy resources, services and control
Energy system operation and management
Nissan Motor Co.
Bornholms Energi og Forsyning
NUVVE Corporation
Period: 01/04/2017 → 30/09/2020
Number of participants: 8
Electric power system, Demand, Frequency control, Electric vehicles, Distributed energy resources, distribution system operation
Acronym: ACES
Number of related Ph.D. students: 1
Project participant:
Træholt, Chresten (Intern)
Sørensen, Thomas Meier (Intern)
Andersen, Peter Bach (Intern)
Hu, Junjie (Intern)
Zecchino, Antonio (Intern)
Thingvad, Andreas (Intern)
Pedersen, Anders Bro (Intern)
Project Coordinator:
Marinelli, Mattia (Intern)

Integration of Gas, District Heating and the Electric Power Systems- Integrated Simulation Framework
Department of Electrical Engineering
Period: 15/12/2016 → 14/12/2019
Number of participants: 4
PhD Student:
Wang, Jiawei (Intern)
Supervisor:
You, Shi (Intern)
Zong, Yi (Intern)
Main Supervisor:
Træholt, Chresten (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Privatist
Project: PhD

Electric Vehicle Integration in an Energy - Optimized Neighbourhood
Department of Electrical Engineering
Period: 01/04/2016 → 31/03/2019
Number of participants: 4
PhD Student:
Gjelaj, Marjan (Intern)
Supervisor:
Andersen, Peter Bach (Intern)
Hashemi Toghroljerdi, Seyedmostafa (Intern)
Main Supervisor:
Træholt, Chresten (Intern)

Financing sources
Source: Internal funding (public)
Electric vehicles in the Nordic countries: Control strategies for coordinated grid services

Nowadays, both Norway and Denmark face challenges in supporting a stable and economic future power system based on renewable energy production and an increasing flexible demand based on electric vehicles (EV). Specifically, the main challenge is to address the adverse effects that the EVs may have on local distribution lines (distribution system operator (DSO) perspective) and enhance their usage to optimize utilization of national renewables, here under the high wind power penetration (transmission system operator (TSO) perspective).

The research emphasis is on power and energy services that EVs can provide both locally and system-wide. Three main topics will be strongly faced:

1. Identification of the technical benefits that ancillary service provision from EVs may provide. EVs may be considered as active grid components and not just mere large loads that cause technical issues on the grid. Under the above mentioned circumstances, also the barriers to EVs grid support services (imposed for instance by national/European grid codes or by the necessity of economic advantages to the EV owner for grid support – also just for the availability) will be identified and classified.

2. Balance of prioritization regarding services between DSO and TSO. This problem comes from the TSOs’ need of grid stability services from small dispatched units, due to displacement of big power plants which traditionally assure reliable grid services. At the same time, it is in the interest of the DSO not to have power provision from distributed energy sources violating the local grid constraints.

3. Common solutions for EV integration across the Nordic countries. Considering the existence of two distinct Danish synchronous regions (DK1 and DK2) managed by the same national TSO and considering that DK2 and Norway, although belonging to the same synchronous region, are managed by two independent TSOs, the investigation will face EVs’ grid support services replicability in different contexts (different constrains). Studies will also consider guidelines and trends at European level (ENTSOE).

Through the usage of dedicated simulation platforms, such as Matlab SimPowerSystems and DIgSILENT PowerFactory, static study scenarios - unbalanced and balanced load flows - as well as optimal power flows and transient analysis will be conducted primarily in order to analyze network components' overloading and voltage violations. Furthermore, micro-grid analysis with different generation sets and EV management will be tested at the DTU facilities including both the Electric Lab of Lyngby Campus and SYSLAB in Risø Campus as well as EVLab that spans both the campuses. The PhD student will be kept in the loop of current and relevant EV projects both at DTU (EnergyLab Nordhavn and Parker) and NTNU (The Smartgrids centre, Smartgrids lab, OADE and ChargeFlex project).

Department of Electrical Engineering

Center for Electric Power and Energy

Energy resources, services and control

Energy system operation and management

Period: 15/12/2015 → 14/12/2018

Number of participants: 4

Electric vehicles, Smart Grid, Distributed energy resources

Project participant:

Zecchino, Antonio (Intern)
Supervisor:
Marinelli, Mattia (Intern)
Korpås, Magnus (Ekstern)
Main Supervisor:
Træholt, Chresten (Intern)

Documents:

Short description of the PhD project

Project
Main Supervisor:
Marinelli, Mattia (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU)
Project: PhD

EnergyLab Nordhavn - New Urban Energy Infrastructures
Department of Electrical Engineering
Center for Electric Power and Energy
Energy resources, services and control
Electricity markets and energy analytics
Energy system operation and management
Department of Applied Mathematics and Computer Science
Department of Civil Engineering
Section for Building Energy
Section for Indoor Climate and Building Physics
Department of Mechanical Engineering
Thermal Energy
HOFOR A/S
Balslev Consulting Engineers A/S
METRO THERM A/S
ABB Group
Københavns Kommune
By og Havn
Radius Elnet
CleanCharge Solutions
Period: 01/04/2015 → 31/03/2019
Number of participants: 20
Acronym: ELN
Number of related Ph.D. students: 9
Project participant:
Hashemi Toghroljerdi, Seyedmostafa (Intern)
Østergaard, Jacob (Intern)
Træholt, Chresten (Intern)
Pinson, Pierre (Intern)
Mitridati, Lesia Marie-Jeanne Mariane (Intern)
Klyapovskiy, Sergey (Intern)
Le Ray, Guillaume (Intern)
Gjelaj, Marjan (Intern)
You, Shi (Intern)
Harrestrup, Maria (Intern)
Rode, Carsten (Intern)
Elmegaard, Brian (Intern)
Ommen, Torben Schmidt (Intern)
Foteinaki, Kyriaki (Intern)
Luc, Katarzyna Marta (Intern)
Pieper, Henrik (Intern)
Meesenburg, Wiebke (Intern)
Mitridati, Lesia Marie-Jeanne Mariane (Intern)
Le Ray, Guillaume (Intern)
Project Manager, organisational:
Greisen, Christoffer (Intern)

Relations
Activities:
Performance analysis of heat pumps utilizing different low temperature heat sources to supply district heating
Publications:
Efficient Control of Active Transformers for Increasing the PV Hosting Capacity of LV Grids
Optimal Design of DC Fast-Charging Stations for EVs in Low Voltage Grids
Cost-Benefit Analysis of a Novel DC Fast-Charging Station with a Local Battery Storage for EVs
Active and reactive power support of MV distribution systems using battery energy storage
Efficient Control of Energy Storage for Increasing the PV Hosting Capacity of LV Grids
Optimal usage of low temperature heat sources to supply district heating by heat pumps
DC Fast-Charging Stations for EVs Controlled by a Local Battery Storage in Low Voltage Grids
Methods and Strategies for Overvoltage Prevention in Low Voltage Distribution Systems with PV

Observability and decision support for supervision of distributed power system control

Department of Electrical Engineering
Period: 15/12/2014 → 14/12/2017
Number of participants: 7
Phd Student:
Pertl, Michael (Intern)
Supervisor:
Heussen, Kai (Intern)
Main Supervisor:
Bindner, Henrik W. (Intern)
Examiner:
Træholt, Chresten (Intern)
Keane, Andrew (Ekstern)
Turri, Roberto (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Samfinansieret - Andet
Project: PhD

Distribution network observability and development of decision support features for real-time operation of 2030 power system

Department of Electrical Engineering
Period: 01/10/2014 → 26/09/2017
Number of participants: 6
Phd Student:
Prostejovsky, Alexander Maria (Intern)
Supervisor:
Kok, Koen (Intern)
Main Supervisor:
Bindner, Henrik W. (Intern)
Examiner:
Træholt, Chresten (Intern)
Monti, Antonello (Ekstern)
Nordström, Lars Martin (Ekstern)

**Financing sources**
Source: Internal funding (public)
Name of research programme: Samfinansieret - Andet

**Relations**
Publications:
Increased Observability in Electric Distribution Grids
Project: PhD

**Robust HT-MEAs for Dynamic Operation under Smart Grid Conditions**
Department of Electrical Engineering
Center for Electric Power and Energy
Energy resources, services and control
Department of Energy Conversion and Storage
Proton conductors
Period: 01/08/2014 → 01/08/2017
Number of participants: 3
Acronym: SmartMEA
Project participant:
Pensini, Alessandro (Intern)
Træholt, Chresten (Intern)
Project Manager, organisational:
Jensen, Jens Oluf (Intern)

**Concepts, capacities and Methods for Testing EV Systems and their Interoperability within the Smart Grids**
PhD project
Department of Electrical Engineering
Center for Electric Power and Energy
Period: 01/08/2014 → 01/08/2017
Number of participants: 4
Acronym: COTEVOS
Number of related Ph.D. students: 1
Project participant:
Træholt, Chresten (Intern)
Andersen, Peter Bach (Intern)
Marinelli, Mattia (Intern)
Phd Student:
Martinenas, Sergejus (Intern)

**Enabling Technologies for Smart Grid Integration of Electric Vehicles**
Department of Electrical Engineering
Period: 01/08/2014 → 31/07/2017
Number of participants: 7
Phd Student:
Martinenas, Sergejus (Intern)
Supervisor:
Andersen, Peter Bach (Intern)
Marinelli, Mattia (Intern)
Main Supervisor:
Træholt, Chresten (Intern)
Control strategies and modelling of electric vehicles in the distribution network

Department of Electrical Engineering
Period: 15/12/2013 → 14/06/2017
Number of participants: 7
Phd Student:
Knezovic, Katarina (Intern)
Supervisor:
Andersen, Peter Bach (Intern)
Marinelli, Mattia (Intern)
Main Supervisor:
Træholt, Chresten (Intern)
Examiner:
Kok, Koen (Intern)
Korpås, Magnus (Ekstern)
Paolone, Mario (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Samfinansieret - Andet
Project: PhD

Nikola - Intelligent electric vehicle integration

Nikola is a Danish research and demonstration project with a focus on the synergies between the electric vehicle (EV) and the power system.

With sufficient control and communication it is possible to influence the timing, rate and direction of the power and energy
exchanged between the EV battery and the grid. This ability can be used in a set of "services" that bring value to the power system, the EV owner and society in general. Nikola seeks to thoroughly investigate such services, to explore the technologies that can enable them and finally to demonstrate them through both simulations and in-field testing.

Department of Electrical Engineering
Center for Electric Power and Energy

Energy resources, services and control
Period: 01/06/2013 → 31/05/2016
Number of participants: 5
Smart Grid, Electric vehicles
Acronym: Nikola
Project participant:
Marinelli, Mattia (Intern)
Andersen, Peter Bach (Intern)
Knezovic, Katarina (Intern)
Martinenas, Sergejus (Intern)
Træholt, Chresten (Intern)

Relations
Activities:
Enhancing the role of EVs in the smart grid: Resources or threats to power system operation? Trends and research drivers in Europe
Publications:
A Dynamic Behaviour Analysis on the Frequency Control Capability of Electric Vehicles
Comparative Analysis of Possible Designs for Flexible Distribution System Operation
Enhancing the Role of Electric Vehicles in the Power Grid: Field Validation of Multiple Ancillary Services
Electric vehicle data acquisition system
Implementation and Demonstration of Grid Frequency Support by V2G Enabled Electric Vehicle
Phase Balancing by Means of Electric Vehicles Single-Phase Connection Shifting in a Low Voltage Danish Grid
Standards for EV charging and their usability for providing V2G services in the primary reserve market
Economic Comparison of Electric Vehicles Performing Unidirectional and Bidirectional Frequency Control in Denmark with Practical Validation
Analysis of Voltage Support by Electric Vehicles and Photovoltaic in a Real Danish Low Voltage Network
Distribution Grid Services and Flexibility Provision by Electric Vehicles: a Review of Options
The Nikola project intelligent electric vehicle integration
Concurrent Provision of Frequency Regulation and Overvoltage Support by Electric Vehicles in a Real Danish Low Voltage Network
EV owner smart grid involvement
Electric Vehicle Smart Charging using Dynamic Price Signal

Dynamic Coverage and Flow Coordination in Multi-Agent Networks

Department of Electrical Engineering
Period: 15/05/2013 → 08/02/2017
Number of participants: 7
Phd Student:
Aabrandt, Andreas (Intern)
Supervisor:
Hansen, Vagn Lundsgaard (Intern)
Poulsen, Bjarne (Intern)
Main Supervisor:
Træholt, Chresten (Intern)
Examiner:
Wu, Qiuwei (Intern)
Jensen, Anders Nedergaard (Ekstern)
Scaglione, Anna (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU) Samf.

Relations
Publications:
Algebraic Varieties and System Design
Project: PhD

Real-Time Assessment of Voltage Stability (tentative)
Department of Electrical Engineering
Period: 15/01/2013 → 30/09/2016
Number of participants: 6
Phd Student:
Perez, Angel (Intern)
Supervisor:
Jóhannsson, Hjörtur (Intern)
Main Supervisor:
Østergaard, Jacob (Intern)
Examiner:
Træholt, Chresten (Intern)
Chow, Joe H. (Ekstern)
Uhlen, Kjetil (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Offentlig finansiering
Project: PhD

Optimal Operation of Distribution Networks with Electrification of Transport and Heating in Nordic Region
Department of Electrical Engineering
Period: 01/10/2012 → 16/03/2016
Number of participants: 6
Phd Student:
Liu, Zhaoxi (Intern)
Supervisor:
Wu, Qiuwei (Intern)
Main Supervisor:
Nielsen, Arne Hejde (Intern)
Examiner:
Træholt, Chresten (Intern)
Sun, Hongbin (Ekstern)
Wang, Lingfeng (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU) Samf.
Project: PhD

Coordinated Control of Wind Power Plants and Energy Storage Systems
Department of Electrical Engineering
Period: 15/10/2011 → 27/02/2015
Number of participants: 6
Phd Student:
Zhao, Haoran (Intern)
Supervisor:
Rasmussen, Claus Nygaard (Intern)
Main Supervisor: Wu, Qiuwei (Intern)
Examiner: Træholt, Chresten (Intern)
Pöller, Markus (Ekstern)
Zhang, Boming (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU) Samf.
Project: PhD

Energy storage and energy system integration
Department of Electrical Engineering
Period: 01/10/2011 → 06/07/2017
Number of participants: 7
Phd Student: Pensini, Alessandro (Intern)
Supervisor: Rasmussen, Claus Nygaard (Intern)
Yang, Guangya (Intern)
Main Supervisor: Træholt, Chresten (Intern)
Examiner: Bindner, Henrik W. (Intern)
Greiner, Martin O. W. (Ekstern)
Jenkins, Bryan M. (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU) Samf.
Project: PhD

31 US-Denmark Summer Program
Department of Electrical Engineering
Center for Electric Power and Energy
Energy resources, services and control
University of California, Santa Cruz
University of California at Davis
Aalborg University
Period: 24/07/2011 → 31/12/2016
Number of participants: 1
Summer school, summer workshop, master course, 4 week intensive
Project participant: Træholt, Chresten (Intern)

Network and control of future intelligent power system
Department of Electrical Engineering
Period: 01/02/2011 → 20/08/2014
Number of participants: 6
Phd Student: Hu, Junjie (Intern)
Supervisor:
Lind, Morten (Intern)
Main Supervisor:
Østergaard, Jacob (Intern)
Examiner:
Træholt, Chresten (Intern)
Kok, J. Koen (Ekstern)
Lehnhoff, Sebastian (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Privatist
Project: PhD

Methods for Early Warning and Early Prevention of Voltage Instability

Department of Electrical Engineering
Period: 01/06/2010 → 26/11/2013
Number of participants: 7
Phd Student:
Dmitrova, Evgenia (Intern)
Supervisor:
Jóhannsson, Hjörtur (Intern)
Jóhannsson, Hjörtur (Intern)
Main Supervisor:
Nielsen, Arne Hejde (Intern)
Examiner:
Træholt, Chresten (Intern)
Makarov, Yuri V. (Ekstern)
Samuelsson, Olof (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU) Samf.
Project: PhD

Electric vehicles in the Electric Power System with high penetration of Wind Power - Charge/discharge infrastructure

Department of Electrical Engineering
Period: 01/10/2009 → 15/08/2013
Number of participants: 6
Phd Student:
Marra, Francesco (Intern)
Supervisor:
Larsen, Esben (Intern)
Main Supervisor:
Træholt, Chresten (Intern)
Examiner:
Bindner, Henrik W. (Intern)
Bollen, Math (Ekstern)
Lopes, João A. Peças (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut, samfinansiering
Project: PhD

Real-Time Analysis of an Active Distribution Network - Coordinated Frequency Control for Islanding

Department of Electrical Engineering
Period: 01/08/2009 → 04/04/2013
Number of participants: 6
Phd Student: Cha, Seung-Tae (Intern)
Supervisor: Wu, Qiuwei (Intern)
Main Supervisor: Østergaard, Jacob (Intern)
Examiner: Træholt, Chresten (Intern)
Marnay, Chris (Ekstern)
Repo, Sami Petteri (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: 1/3 FUU, 1/3 inst 1/3 Andet
Project: PhD

Communication architecture for service based control of distributed power systems
Department of Electrical Engineering
Period: 01/11/2008 → 15/06/2016
Number of participants: 5
Phd Student: Kullmann, Daniel (Intern)
Main Supervisor: Bindner, Henrik W. (Intern)
Examiner: Træholt, Chresten (Intern)
Jørgensen, Bo Nørregaard (Ekstern)
Sonnenschein, Michael (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU) Samf.
Project: PhD

Superconducting Wind Turbine Generators
Department of Electrical Engineering
Period: 01/05/2008 → 21/08/2012
Number of participants: 7
Phd Student: Mijatovic, Nenad (Intern)
Supervisor: Abrahamsen, Asger Bech (Intern)
Træholt, Chresten (Intern)
Main Supervisor: Jensen, Bogi Bech (Intern)
Examiner: Nielsen, Arne Hejde (Intern)
Masson, Philippe J. (Ekstern)
Polinder, Henk (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Globaliseringsmidler
Project: PhD
Generic Virtual Power Plant for Micro Combined Heat and Power Units

Department of Electrical Engineering
Period: 01/10/2007 → 23/03/2011
Number of participants: 6
Phd Student:
You, Shi (Intern)
Supervisor:
Poulsen, Bjørne (Intern)
Main Supervisor:
Træholt, Chresten (Intern)
Examiner:
Rasmussen, Claus Nygaard (Intern)
Kempton, Willett (Intern)
Mølbak, Tommy (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: DTU, Samfinansiering
Project: PhD

PowerLabDK : An Experimental Research Platform for Electric Power and Energy

Department of Electrical Engineering
Risø National Laboratory for Sustainable Energy
Centre for Electric Technology
University of Copenhagen
Østkraft A/S
Period: 01/08/2007 → 01/12/2008
Number of participants: 9
Project ID: 55500
Project participant:
Nielsen, Arne Hejde (Intern)
Lind, Morten (Intern)
Holbøll, Joachim (Intern)
Træholt, Chresten (Intern)
Sørensen, Poul Ejnar (Intern)
Bindner, Henrik W. (Intern)
Friesel, Anna (Ekstern)
Sjøberg, Poul-Erik (Ekstern)
Project Manager, organisational:
Østergaard, Jacob (Intern)

Financing sources
Source: Forskningsrådene - Andre
Name of research programme: Forskningsrådene - Andre
Amount: 500,000.00 Danish Kroner
Project
Kompositbaserede Luftledningssystemer

Department of Electrical Engineering
Period: 01/01/2007 → 22/09/2010
Number of participants: 6
Phd Student:
Sørensen, Thomas Kjærgaard (Intern)
Supervisor:
Mikkelsen, Søren Damsgaard (Ekstern)
Main Supervisor:
Holbøll, Joachim (Intern)
Examiner:
Træholt, Chresten (Intern)
Høidalen, Hans Kristian (Ekstern)
Sørensen (fadrådt), Troels (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Ansat eksternt
Project: PhD

System integration of distributed energy resources - ICT, ancillary services, and markets

Department of Electrical Engineering
Period: 01/08/2006 → 23/03/2011
Number of participants: 5
Phd Student:
Nyeng, Preben (Intern)
Main Supervisor:
Østergaard, Jacob (Intern)
Examiner:
Træholt, Chresten (Intern)
Bertling, Lina (Ekstern)
Järventausta, Pertti (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: DTU-lønnet stipendie
Project: PhD

EUCAS 2001 Conference - Copenhagen

Department of Electric Power Engineering
Department of Physics
Department of Electrical Engineering
DIS Congress Service
Nordic Superconductor Technology
Period: 01/08/1999 → 01/11/2001
Number of participants: 13
Project participant:
Hald, Britta (Intern)
Herse, Erik (Intern)
Hvirgeltoft, Georg (Intern)
Jensen, Kim Høj (Intern)
Ph.d.project, Carsten Rasmussen: Superconducting power cable terminations
This ph.d. project is based on strategic research to investigate theoretically and experimentally the design and construction of a superconducting cable termination.

*Department of Electric Power Engineering*
*Period: 01/05/1997 → 30/04/2000*
*Number of participants: 8*
*Project participant:*
  - Holbøll, Joachim (Intern)
  - Däumling (fratrådt), Manfred (Intern)
  - Kyhle, Anders (Intern)
  - Olsen, Søren Krüger (Intern)
  - Nielsen, Jørgen Nygård (Intern)
  - Træholt, Chresten (Intern)
  - Pinholt, Henriette Understrup (Intern)
*Project Manager, organisational:*
  - Tønnesen, Ole (Intern)

**Financing sources**
*Source: Unknown*
*Name of research programme: Ukendt*
*Amount: 3,000,000.00 Danish Kroner*

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**Electron Microscope Investigation of GraAs/AlxGaj**

*Technical University of Denmark*
*Period: 01/08/1988 → 24/03/1995*
*Number of participants: 1*
*Phd Student:*
  - Træholt, Chresten (Intern)

**Financing sources**
*Source: Internal funding (public)*
*Name of research programme: Forskningsrådsstipendium*
*Project: PhD*