Photovoltaic mismatch losses caused by moving clouds

Mismatch losses is a major issue in the photovoltaic (PV) system and are mainly caused by partial shading; largest mismatch losses are caused by sharp shadows. These shadows are a typical problem for rooftop and residential installations. In large-scale PV plants, partial shading is mostly caused by moving clouds which produce gentle irradiance transitions causing typically only minor irradiance differences between adjacent PV modules.

This paper presents a study of the mismatch losses of PV arrays with various layouts and electrical configurations during around 27,000 irradiance transitions identified in measured irradiance data. The overall effect of the mismatch losses caused by moving clouds on the energy production of PV plants was also studied. The study was conducted using a mathematical model of irradiance transitions and an experimentally verified MATLAB/Simulink model of a PV module.

The relative mismatch losses during the identified irradiance transitions ranged from 1.4% to 4.0% depending on the electrical configuration and layout of the PV array. The overall effect of the mismatch losses caused by moving clouds on the total electricity production of PV arrays was about 0.5% for the PV array with strings of 28 PV modules and substantially smaller for arrays with shorter strings. The proportions of the total mismatch losses caused by very dark or highly transparent clouds were small. About 70% of the total mismatch losses were caused by shadow edges with shading strengths ranging between 40% and 80%. These results indicate that the mismatch losses caused by moving clouds are not a major problem for large-scale PV plants. An interesting finding from a practical point of view is that the mismatch losses increase the rate of power fluctuations compared to the rate of irradiance fluctuations.
Nanocomposite Polypropylene For DC Cables And Capacitors: A New European Project

This paper presents the scientific background of a new European project, GRIDABLE, which was launched at the beginning of 2017 and has to deliver results in manufacturing and characterization of LV-MV capacitors and MV-HV cables for DC application. The innovation is in the development of nanostructured materials based on polypropylene and silica, and the relevant capacitor and cable manufacturing procedures. The initial results regarding the electrical properties of PP-SiO2 materials, which have brought to the proposal of this project, are presented in this paper, focusing on breakdown strength and space charge measurements performed on nanofilled PP films for capacitors.

Resistive current waveform as a tool to identify degraded parts of polymeric surge arresters subjected to internal moisture

Aspects of moisture ingress in polymer housed surge arresters

Polymers have been extensively applied in the industry, especially in energy system e.g. due to their good processability and insulation properties. However, all polymers are permeable in different extent, which requires a good knowledge about the process of permeation through these materials. In this study the moisture dynamics of four different surge arresters were studied in several ways,—at first by analysing the moisture diffusion properties of the housing polymers and finally by testing the full arrester structures against moisture ingress. Housing polymer composites were evaluated using thermogravimetric analysis and differential scanning calorimetry while the polymers' ability to withstand moisture diffusion was studied by water vapor transmission rate measurements. Moisture ingress behavior of the full surge arresters was examined by daily measurements of internal resistive leakage current along 30 days immersion test. Although correlations were found between the material composition and the diffusivity through the polymer, the moisture dynamic is deemed to be much more complex in the full surge arrester. Moisture permeation through separate housing material samples was typically high compared to internal leakage current formed in real arresters which highlights the main conclusion drawn,—internal structures and long term quality of interfaces are the key issues in preventing moisture induced degradation in metal oxide surge arresters.

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Authors: Montanari, G. C., Seri, P., Karttunen, M., Paajanen, M., Lahti, K., Rytöluoto, I.
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General information
Effects of PV array layout, electrical configuration and geographic orientation on mismatch losses caused by moving clouds

The mismatch losses of photovoltaic (PV) systems are mainly caused by partial shading and the largest mismatch losses are caused by sharp shadows. However, in large scale PV plants majority of shading events is caused by moving clouds which lead to gentle irradiance transitions causing typically only minor irradiance differences between adjacent PV modules. Irradiance transitions caused by the edges of cloud shadows have an average length of almost 150 m meaning that even the largest PV power plants are widely affected by them. In addition of mismatch losses, these irradiance transitions can lead to failures in maximum power point tracking and cause significant fluctuations in the output power of PV systems. In this paper, the effects of PV array shape, electrical configuration and orientation on mismatch losses caused by moving clouds were studied based on apparent velocity and other measured characteristics of roughly 27,000 irradiance transitions. The study was conducted using a mathematical model and parametrisation method of irradiance transitions and an experimentally verified simulation model of a PV module based on the well-known one-diode model of a PV cell. The studied electrical PV array configurations were series-parallel, total-cross-tied and multi-string. The results of this study confirmed a prior conclusion, namely, that the mismatch losses decrease with decreasing PV string length. It was also found that the array orientation has a considerable effect on the mismatch losses of the studied array layouts. The mismatch losses were the smallest when the dominant direction of movement of the shadow edges was perpendicular to the PV strings. The differences in the mismatch losses between the studied electrical array configurations were very small. The results indicated that the mismatch losses caused by moving clouds have only a minor effect on the overall efficiency of PV arrays.
Utilization Possibilities of Electrical Energy Storages in Households’ Energy Management in Finland

Electrical energy storage is one option for making the environmental impact of households’ energy usage smaller. A storage could improve the profitability of household level electricity production and could also decrease the load in the electricity networks. So far, poor profitability has been the greatest barrier to the use of storages. The battery systems prices have been high and the benefits difficult to predict. The benefit of the use of storage and the factors affecting to the benefits are studied in this paper. For this purpose, a simulator has been designed for modelling the energy storage as part of the household’s electricity grid. The control of the storage significantly affects to the amount of benefits. The developed control method of the simulator aims to maximize the benefits. The simulations took into account the variables that are not accurately known when the storage is controlled. For these variables, such as e.g. future consumption, various forecasts were formed.

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Organisations: Electrical Energy Engineering, Research area: Power engineering
Authors: Koskela, J., Rautiainen, A., Järventausta, P.
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Publication information
Simulation Environment for Centralized Protection and Control applying dSPACE and RTDS with IEC 61850 9-2 Communication

The role of centralized protection and control system as a novel approach is important in terms of the protection of power networks. In centralized protection and control system, centralized computer receives the phase measurements from IEDs through the IEC 61850 9-2 sampled values. Based on these measurements, centralized computer instructs IEDs to perform necessary actions, according to the algorithms, to provide protection against faults. The aim of this paper is to describe the present centralized protection and control simulation environment at Tampere University of Technology. The present simulation environment has the ability to replay the pcap file and generate network traffic like real world traffic. In the present simulation environment, high resistance single phase to earth fault algorithm is implemented and successfully verified. In this simulation environment, dSPACE is used as centralized computer and real time digital simulator (RTDS) is used to simulate the network and IEDs in real time. The hardware of RTDS sends the measured data to the dSPACE IEC 61850 9-2 sampled values format. The simulation environment will enable researchers to test the protection algorithms in the real time e.g. their time performances.

Development and Testing of New Equipment for Faulty Phase Earthing Applying RTDS

In neutral isolated MV networks the earth fault arc is typically extinguished by an automatic reclosing function. It causes a short interruption for the feeder in question. The earth fault arc can also be extinguished using shunt circuit-breaker to earth the faulty arc phase temporarily at the feeding, typically 110/20 kV substation. The functioning of the shunt circuit-breaker does not change phase-to-phase voltages of the MV system. Thereby voltage breaks or dips to customers or DG units can be avoided. The shunt circuit-breaker is used for reducing the harmful short interruptions experienced by the customers and electricity producers connected to MV or LV networks. This paper describes the development of the modern shunt circuit-breaker equipment. The main attention was paid to the development, testing and prototyping of the novel shunt circuit-breaker. The developed algorithm for the faulty phase selection was implemented to the feeder terminal. The prototype equipment including the shunt circuit-breaker, the programmable logic controller and IED was tested applying RTDS (Real Time Digital Simulator) environment. The prototype has also been installed and tested with artificial earth faults in the real network.
Development of Modern Phase Earthing System for Improving Quality of Supply in MV Network

This paper introduces the methods development of the modern phase earthing system. The target is reducing the harmful short interruptions experienced by the customers and electricity producers with temporary phase-to-earth faults of an MV system. Especially in neutral isolated MV networks the earth fault arc does not usually become extinct without an automatic reclosing function. It can be extinguished using shunt circuitbreaker to earth the faulty phase temporarily at the feeding primary substation. The functioning of the shunt-circuit breaker does not cause any voltage break to customers or DG units connected to the MV or LV system. An essential requirement enabling the applying of the phase earthing is that the residual current at the fault location must be determined reliably in order to evaluate fulfilling of the touch voltage regulations. The inexact information on the magnitude of the residual current has restricted the utilization of phase earthing. The main attention was paid to the modeling of the phase earthing system for developing the method for determining the residual phase-to-earth current. The developed novel algorithm was tested applying PSCAD simulation environment. The results show that the residual fault current can be calculated with the actual fault case (e.g. IED or Centralized Protection System, CPS). The prototype of shunt circuit-breaker has also been installed and tested with artificial earth faults.

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Research output: Scientific - peer-review › Review Article
A comparative study between surge arrester monitoring through capacitive/resistive measurement bridge and digital decomposition

In order to improve the reliability of the energy system, a variety of techniques to access the condition monitoring of important equipment connected to the network have been developed in the past decades. However, it is important to choose the adequate method when evaluating the behavior of these devices. In this way, the current work aims to compare three techniques used to evaluate the condition of metal oxide surge arrester based on the decomposition of leakage current into its capacitive and resistive components. Each method was described in detail and their results compared.

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Detection of Subsynchronous Torsional Oscillation Frequencies Using Phasor Measurement

This paper presents a non-invasive and easy to implement technique using phasor measurement units for accurate estimation of subsynchronous torsional frequencies. This information is relevant for the optimal design of HVDC subsynchronous damping controllers that enhance the effect of HVDC on subsynchronous damping. The method is rigorously justified using mathematical proofs as well as thorough EMT simulations. The method was implemented in the Finnish transmission network and proved to be effective.

General information
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Scopus rating (2013): SJR 1.64 SNIP 2.845 CiteScore 3.51
Scopus rating (2012): SJR 1.386 SNIP 2.688 CiteScore 3.28
Scopus rating (2011): SJR 1.117 SNIP 2.257 CiteScore 2.89
Scopus rating (2010): SJR 1.172 SNIP 2.068
Scopus rating (2009): SJR 0.985 SNIP 2.053
Scopus rating (2008): SJR 1.12 SNIP 2.157
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Scopus rating (2006): SJR 0.944 SNIP 1.821
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Improving Disturbance Management with Combined Electricity and Mobile Network Situation Awareness System

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Pohjoismaiden energiapoliitikka 2030: Hiilineutraalimpaan energiajärjestelmään osin yhdessä, osin eri polkuja pitkin

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Research output: Professional › Discussion paper

Tammikuun tehopiikki – mitä tapahtui 7.1.2016? Miten tehoa hallitaan paremmin jatkossa?

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Organisations: Department of Civil Engineering, Research group: Life-cycle Economics, Department of Automation Science and Engineering, Research area: Measurement Technology and Process Control, Department of Electrical Engineering, Research area: Power engineering, Research group: Construction Processes, University of Tampere
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Publication information
Single-source multibattery solar charger: Case study and implementation issues

In this paper, design process and functionality of a portable single-panel dual-battery solar charger prototype are presented, achieving energy density of 571 Wh kg⁻¹ during a typical 3-day infantry mission. The device may instantaneously charge up to two Li-ion MR-2791 batteries, supporting plug-and-play operation. The system consists of a lightweight custom solar panel, based on 20% efficient monocrystalline photovoltaics, and an intelligent power processing module. The panel contains eight transparent polymer-encapsulated and camouflaged series-connected six solar cell packs with antiparallel diodes, allowing partial shading operation. The power processing module consists of two synchronous current-mode-controlled buck converters, digital signal processor, and a microcontroller, supporting both maximum power point tracking of the solar panel with partial shading detection and multimode charging of Li-ion packs while instantaneously communicating with the batteries. Power management algorithmic design is presented, based on ensuring system stability while supporting the required operation modes. System implementation stages and underlying issues are thoroughly discussed, and utilized hardware components are presented in detail. Experimental results of system testing under real outdoor conditions are presented to demonstrate the device functionality and energy yield capabilities.

General information

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Scopus rating (2011): SJR 3.251 SNIP 5.999 CiteScore 6.81
Scopus rating (2010): SJR 3.749 SNIP 4.317
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Scopus rating (2008): SJR 2.537 SNIP 2.473
Scopus rating (2007): SJR 1.711 SNIP 2.124
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Scopus rating (2005): SJR 1.774 SNIP 3.07
Scopus rating (2004): SJR 0.852 SNIP 1.671
Scopus rating (2003): SJR 0.763 SNIP 1.489
Scopus rating (2002): SJR 1.658 SNIP 1.742
Scopus rating (2001): SJR 1.651 SNIP 1.714
Scopus rating (2000): SJR 0.934 SNIP 1.567
Scopus rating (1999): SJR 0.673 SNIP 1.076
Factors Affecting Efficiency of LVDC Distribution Network – Power Electronics Perspective

The power distribution network will be changed towards the future Smart Grid due to increased number of installed renewable power generation units to fulfill the tightened environmental regulation. The control of the future Smart Grid will be challenging due to increased number of renewable power generation units, which are variable in nature, and at the same time, the customers are highly dependent on uninterruptable, high quality power supply. The Smart Grid control is intensively studied. It can be concluded that the control might be simpler and the grid operation more reliable if the AC grid would be replaced by DC grid. However, the detailed energy efficiency analysis of the DC grid is not thoroughly studied. The efficiency and total lifetime costs are the key parameters when the network owners consider the future grid structure.

This thesis addresses the factors, which affect the energy efficiency of the low voltage DC (LVDC) distribution network from power electronics perspective. The power loss models for the converters and their AC filters are developed and verified by measurements. The impact on the converter topology, used power semiconductor switches, AC filter design and inductor core material, DC network configuration, customer behavior, the need of DC voltage balancing in the bipolar DC network as well as the grounding issues to fulfill the electrical safety standards are treated. For facilitating the design of cost effective LVDC distribution networks, the total power losses of the network with different configurations are evaluated and compared.

It is revealed that the used filter inductor core material has a significant impact on the power losses of the LVDC distribution network. The inductor core material having low high-frequency power loss characteristics, such as amorphous alloy, is recommended. The LVDC distribution network should be grounded to minimize the power losses whenever it is possible according to the local safety standardization and grounding conditions. The three-level NPC converters connected to 1500 VDC should be used to minimize the power losses. The grid-frequency isolation transformer is the main power loss source if the galvanic isolation is needed to isolate the ungrounded LVDC distribution network and the grounded customer electrical installations. In this case, the highest energy efficiency is achieved by using two- or three-level converters connected to 750 VDC if the DC cable length is less than 600 m. Otherwise, slightly higher energy efficiency is achieved by using three-level converters connected to 1500 VDC. Therefore, voltage transformation ratio of the isolation transformer must be 800V/400V instead of 400V/400V. Moreover, the efficiency of the power converters is increased by using SiC MOSFETs instead of conventional IGBTs as power semiconductor switches.
Aspects of Electric Vehicles and Demand Response in Electricity Grids

The growing global energy demand combined with limited resources of fossil energy (especially crude oil), climate change and other environmental issues, the energy system has faced significant challenges. There is significant pressure to diversify the energy sources towards more sustainable choices and to increase energy efficiency. Shifting gradually from the use of fossil fuels to use of renewable energy sources is a long way to go, and to make it economically feasible requires a significant amount of will, effort and innovation.

This thesis deals with two parts of the energy system: the electrical energy system and the energy system of road transportation. A “smart” electrical energy system of the future includes the flexibility of electricity demand, i.e. demand response (DR), enabled by different types of incentives and offering many potential advantages. A road transportation system of the future can include significant amount of electric vehicles (full electric vehicles – full EVs and plug-in hybrid electric vehicles – PHEVs) as part of the vehicle fleet. These vehicles could also participate in the operation of an electrical power system. This thesis discusses electric vehicles and demand response in smart grid context.

The most important results and findings of the thesis are the following. In Finland, PHEVs could offer a significant proportion or even most of the benefits of EVs even with a quite modest charging infrastructure, and simultaneously the most severe obstacles of full EVs could be avoided or at least mitigated. In this thesis, a flexible methodology for modeling PHEV charging load using National Travel Survey data has been developed. Statistical PHEV charging load models, taking into account modeled statistical distributions of the loads, have been used by two different real DNOs in their network information systems to assess the impacts of EVs on distribution network planning in urban networks. It seems that high amounts of EVs fit well into Finnish distribution networks, but in certain cases demand response of electric vehicles would be reasonable. Electric vehicles, some DR actions and other changes in electricity use can increase peak powers in distribution networks. New distribution tariffs have been developed and simulated in a real distribution network with the purpose of encouraging small electricity customers towards peak load restriction. It seems that these kinds of tariffs would be efficient in restricting the increase of peak powers of spot price based DR, although is seems to be hard to decrease the present peak powers very much in the distribution networks. Different general DR and smart charging concepts have been sketched, and a practical local customer-site peak load control management algorithm of an EV charging station group has been developed as a tool to realize demand response of a group of electric vehicles.
A Versatile Solution for Continuous On-line PD Monitoring

Performance analysis of Q-f droop anti-islanding protection in the presence of mixed types of DG

This paper analyses the performance of a Q-f droop based anti-islanding protection (AIP) scheme when the islanded circuit contains both inverter based DG and directly connected synchronous generator (SG) based DG. It is found that the performance of the AIP method is significantly degraded when SG is present in the island. This is because frequency cannot be directly manipulated by injecting reactive power when SG is present. However, feeding reactive power still indirectly affects frequency and the Q-f droop based AIP scheme thus still facilitates islanding detection. The simulation results aim to bring awareness to which extent the presence of SG degrades the performance of the Q-f droop based AIP.

Smart Frequency Control in Power Transmission Systems Using a BESS

This paper analyses the performance of a Q-f droop based anti-islanding protection (AIP) scheme when the islanded circuit contains both inverter based DG and directly connected synchronous generator (SG) based DG. It is found that the performance of the AIP method is significantly degraded when SG is present in the island. This is because frequency cannot be directly manipulated by injecting reactive power when SG is present. However, feeding reactive power still indirectly affects frequency and the Q-f droop based AIP scheme thus still facilitates islanding detection. The simulation results aim to bring awareness to which extent the presence of SG degrades the performance of the Q-f droop based AIP.
Methodology for Dynamic Stability and Robustness Analysis of Commercial-Power-Module-Based DC-Distributed Systems

The purpose of this thesis is to present dynamic small-signal stability and performance analysis methodology for dc-distributed systems consisting of commercial power modules. Furthermore, the objective is to introduce simple method to state the least conservative margins for robust stability as a single number. In addition, an index characterizing the overall system stability is obtained, based on which different dc-distributed systems can be compared in terms of robustness.

The interconnected systems are prone to impedance-based interactions which might lead to transient-performance degradation or even instability. These systems typically are constructed using commercial converters with unknown internal structure. Therefore, the analysis presented throughout this thesis is based on frequency responses measurable from the input and output terminals. The stability margins are stated utilizing a concept of maximum peak criteria, derived from the behavior of impedance-based sensitivity function that provides a single number to state robust stability. Using this concept, the stability information at every system interface is combined to a meaningful number to state the average robustness of the system. In addition, theoretical formulas are extracted to assess source and load side interactions in order to describe detailed couplings within the system. The presented theoretical analysis methodologies are experimentally validated throughout the thesis.

In this thesis, according to the presented analysis, the least conservative stability margins are provided as a single number guaranteeing robustness. It is also shown that within the interconnected system the robust stability is ensured only if the impedance-based minor-loop gain is determined at the very input or output of each subsystem. Moreover, a complete set of impedance-type internal parameters as well as the formulas according to which the interaction sensitivity can be fully explained and analyzed, is provided. The given formulation can be utilized equally either based on measured frequency responses, time-domain identified internal parameters or extracted analytic transfer functions.

Based on the analysis methodologies presented in this thesis, the stability and performance of interconnected systems consisting of converters with unknown internal structure, can be predicted. Moreover, the provided concept to assess the least conservative stability margins enables to obtain an index to state the overall robust stability of distributed power architecture and thus to compare different systems in terms of stability.
Partial discharge activity in distribution MOSAs due to internal moisture

In order to evaluate if metal oxide surge arrester present any partial discharge (PD) in case of internal moisture and how applicable it is as a condition monitoring diagnostic method, 8 distribution class (Ucov = 20 kV) metal oxide surge arresters (6 silicone housed and 2 Ethylen-Vinylacetate (EVA) housed) from four different manufacturers (A, B, C and D) were submitted to an immersion test for 19 days. The partial discharge and leakage current levels were measured daily. Parameters like largest repeatedly occurring PD magnitude, discharge current and PD repetition rate were recorded for later comparison with power loss calculated from the leakage current. In some of the arresters internal moisture was noticed, however, partial discharge measurement was not as sensitive as power loss. For those samples identified with internal moisture, the partial discharge activity showed a special behavior keeping a limited amplitude itself but presenting a high repetition rate.

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ASJC Scopus subject areas: Electrical and Electronic Engineering
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Research output: Scientific - peer-review › Conference contribution

Compensation of PV generator output power fluctuations with energy storage systems

Photovoltaic generators (PVG) suffer from short-term intermittency of output power. With significant penetration of PV this intermittency can lead to power systems instability and power quality problems. Energy storage systems (ESS) can be used to compensate PV power fluctuations in order to mitigate these problems. In this paper ESS behavior, control and sizing have been investigated to mitigate instabilities caused by PV power plants operating in Northern European conditions through simulations that utilize measurements from the Tampere University of Technology (TUT) Solar PV power station research plant. Continuous synchronized measurements have been recorded with the irradiance and PV module temperature sensor network with a 10 Hz sampling frequency since June 2011. The ESS capacity and power requirements are derived from the simulations for different PVG sizes and PV power ramp rate (RR) limits. The results show how both capacity and power requirements decrease as functions of the RR limit and the PVG size. Also, interesting differences have been noticed compared to similar studies done in Southern European climate, which indicate that the operational climate of the PVG can have an effect on ESS sizing.

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Authors: Schnabel, J., Valkealahti, S.
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ASJC Scopus subject areas: Energy(all)
DOIs: 10.4229/EUPVSEC20152015-5BV.2.6
Research output: Scientific - peer-review › Conference contribution
Recognition of shading events caused by moving clouds and determination of shadow velocity from solar radiation measurements

Fast variability of solar radiation is the main cause of fluctuating photovoltaic (PV) power production and shadows caused by overpassing clouds are the main reason of such variability. Fast irradiance transitions caused by the edges of shadows can lead to situations where the grid inverter is not able to follow the global maximum power point (MPP) causing extra losses. Further, fast fluctuations of the power fed to the electric grid can cause, for example, power balance and quality problems. This paper presents a method to recognize shading events caused by moving clouds from measured irradiance data. The developed recognition method has been used to analyse shading events from 15 months of full-time irradiance recordings and the results of the analysis are presented. Further, the Linear Cloud Edge (LCE) method has been used to determine velocities of the shadows.

General information
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Organisations: Department of Electrical Engineering, Research area: Power engineering
Authors: Lappalainen, K., Valkealahti, S.
Number of pages: 6
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DOIs: 10.4229/EUPVSEC20152015-5AO.7.5
Research output: Scientific - peer-review › Conference contribution

Risk Assessment of Major Storm Situation in Distribution System
Risk and reliability have a significant connection in meaning; both of them are the facts for one inference. High level of risk is resource of lower reliability. Risk management in power system has a variety of different subjects including models, methods and applications. Risk is a mixture of probability of disturbance event and the negative effect of that occurrence. Usually it counted for random accident which has harmful effect on people’s life and environment. In this paper risks study of storm situation modelled. Random failures in power system are the origin of risk and cannot control by staff. Monte-Carlo Simulation (MCS) has used to model the fault frequencies and outage time of customers. The two tools which use in financial studies to make investment decision and applicable in power systems are Value-at-Risk (VaR) and Conditional Value-at-Risk (CVaR) Result of study compared to the actual reliability which confirm the improvement in the reliability of system. It is not possible to predict the precise amount of load value, Concerns of power outage in local area and possibility of a general blackout.

General information
State: Published
Ministry of Education publication type: A4 Article in a conference publication
Organisations: Department of Electrical Engineering, Research area: Power engineering, Smart Energy Systems (SES)
Authors: Dehghani, N., Supponen, A., Repo, S.
Publication date: 1 Sep 2015
Host publication information
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Publisher: IEEE
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DOIs: 10.1109/UPEC.2015.7339808
Research output: Scientific - peer-review › Conference contribution

Low-Voltage DC Distribution—Utilization Potential in a Large Distribution Network Company
Low-voltage direct-current (LVDC) distribution is a promising solution whose benefits are large power transfer capacity with low voltage, high cost savings potential, and improvements to reliability and voltage quality. Tests by the pilot implementation in the distribution system operator (DSO) Elenia Oy have given promising results. The power transfer capacity of the system has been calculated in this paper using voltage drop and maximum load of cable as boundaries. The branches of the medium-voltage network that can be replaced by LVDC distribution are determined based on the calculations and mass computation of the entire distribution area of Elenia Oy. Based on the electrotechnical and
customer outage costs (COC) analyses made, it can be inferred that LVDC distribution has good utilization potential. Based on the power transfer capacity calculations, it is technically possible to replace branch lines up to 8 km long by LVDC distribution which means about 20% of the total medium-voltage network length in the distribution area of Elenia Oy. This means also huge potential in improving the overall reliability of electricity supply and in reducing outage costs of customers which are these days taken into account in the regulation of network business.

**General information**

State: Published

Ministry of Education publication type: A1 Journal article-refereed

Organisations: Department of Electrical Engineering, Research area: Power engineering, Smart Energy Systems (SES), Elenia Oy

Authors: Hakala, T., Lähdeaho, T., Järventusta, P.

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Scopus rating (2015): SJR 1.967 SNIP 2.66 CiteScore 3.96

Scopus rating (2014): SJR 1.726 SNIP 2.693 CiteScore 3.4

Scopus rating (2013): SJR 1.64 SNIP 2.845 CiteScore 3.51

Scopus rating (2012): SJR 1.386 SNIP 2.688 CiteScore 3.28

Scopus rating (2011): SJR 1.117 SNIP 2.257 CiteScore 2.89

Scopus rating (2010): SJR 1.172 SNIP 2.068

Scopus rating (2009): SJR 0.985 SNIP 2.053

Scopus rating (2008): SJR 1.12 SNIP 2.157

Scopus rating (2007): SJR 0.926 SNIP 1.978

Scopus rating (2006): SJR 0.944 SNIP 1.821

Scopus rating (2005): SJR 0.973 SNIP 1.925

Scopus rating (2004): SJR 0.807 SNIP 1.946

Scopus rating (2003): SJR 1.727 SNIP 1.876


Scopus rating (2001): SJR 1.234 SNIP 1.169

Scopus rating (2000): SJR 0.945 SNIP 1.783

Scopus rating (1999): SJR 0.425 SNIP 1.31

Original language: English

ASJC Scopus subject areas: Electrical and Electronic Engineering, Energy Engineering and Power Technology

Keywords: Direct-current distribution, low-voltage direct current (LVDC), LVDC distribution system, power transfer capacity calculation

DOIs: 10.1109/TPWRD.2015.2398199

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Source-ID: 84937893206

Research output: Scientific - peer-review › Article

**Improved adaptive input voltage control of a solar array interfacing current mode controlled boost power stage**

Nonlinear characteristics of photovoltaic generators were recently shown to significantly influence the dynamics of interfacing power stages. Moreover, since the dynamic resistance of photovoltaic generators is both operating point and environmental variables dependent, the combined dynamics exhibits these dependencies as well, burdening control challenge. Typically, linear time invariant input voltage loop controllers (e.g. Proportional-Integral-Derivative) are utilized in photovoltaic applications, designed according to nominal operating conditions. Nevertheless, since actual dynamics is seldom nominal, closed loop performance of such systems varies as well. In this paper, adaptive control method is proposed, allowing to estimate photovoltaic generator resistance online and utilize it to modify the controller parameters such that closed loop performance remains nominal throughout the whole operation range. Unlike previously proposed method, utilizing double-grid-frequency component for estimation purposes and suffering from various drawbacks such as operation point dependence and applicability to single-phase grid connected systems only, the proposed method is based
on harmonic current injection and is independent on operating point and system topology.

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Ministry of Education publication type: A1 Journal article-refereed
Organisations: Department of Electrical Engineering, Research area: Power engineering, Smart Energy Systems (SES), Dept. of Electrical Engineering and Electronics, Ariel University
Authors: Sitbon, M., Schacham, S., Suntio, T., Kuperman, A.
Number of pages: 7
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Volume: 98
ISSN (Print): 0196-8904
Ratings:
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Scopus rating (2015): SJR 2.09 SNIP 2.092 CiteScore 5.24
Scopus rating (2014): SJR 1.854 SNIP 2.835 CiteScore 5.35
Scopus rating (2013): SJR 1.669 SNIP 2.558 CiteScore 4.49
Scopus rating (2012): SJR 1.732 SNIP 2.277 CiteScore 3.72
Scopus rating (2011): SJR 1.292 SNIP 1.846 CiteScore 3.03
Scopus rating (2010): SJR 1.372 SNIP 1.75
Scopus rating (2009): SJR 1.339 SNIP 1.797
Scopus rating (2008): SJR 1.508 SNIP 1.905
Scopus rating (2007): SJR 1.196 SNIP 1.811
Scopus rating (2006): SJR 1.327 SNIP 1.816
Scopus rating (2005): SJR 1.577 SNIP 1.799
Scopus rating (2004): SJR 1.049 SNIP 1.466
Scopus rating (2003): SJR 0.903 SNIP 1.321
Scopus rating (2002): SJR 1.089 SNIP 1.463
Scopus rating (2001): SJR 0.81 SNIP 0.855
Scopus rating (2000): SJR 0.576 SNIP 0.688
Scopus rating (1999): SJR 0.515 SNIP 0.724
Original language: English
Keywords: Adaptive control, Dynamic resistance, Photovoltaic generators
DOIs:
10.1016/j.enconman.2015.03.100
Source: Scopus
Source-ID: 84927949172
Research output: Scientific - peer-review › Article

Real-Time Low Voltage Network Monitoring - ICT Architecture and Field Test Experience
Traditionally, distribution network monitoring has been focused on primary substations (i.e., high voltage/medium voltage level), whereas low voltage (LV) network has not been monitored at all. With rapid growth and penetration of distributed energy resources in LV grids, there is growing interest in extending the real-time monitoring to LV level. The framework program FP7 European Project INTEGRIS proposes an integrated real-time LV network monitoring solution and implements it in a cost-efficient way. This solution integrates smart metering data with secondary substation measurements to get a more accurate and real-time view about LV grid, uses "decentralized" distribution management architecture to optimize data flow, and uses International Electrotechnical Commission 61850 Standard-based interfaces to improve interoperability. This paper focuses on information and communications technology perspective, explains the implementation details of this monitoring solution, and presents its functionality/performance testing results from two distribution system operator field trials and from real-time digital simulator laboratory.

General information
State: Published
Ministry of Education publication type: A1 Journal article-refereed
Change Detection of Electric Customer Behavior Based on AMR measurements

Smart Grids technology is emphasized a lot in the future power system worldwide. Nowadays, the widely used Automatic Meter Reading (AMR) technology in Finland makes it possible to collect customers’ hourly load measurements and to use data analysis methods for customer clustering and load prediction purposes. This paper addresses the detection of possible changes in customers’ behavior. This could for example be a result of changed habitation, heating solution change, installation of solar panels or other equipment. Basic classification and regression methods like K-means and Fuzzy C-means are utilized to analyze the electric customer behavior. The developed method successfully detects various obvious load pattern changes on different customer types. It also offers rough time information regarding at which week the change happens. This behavior change detection method can be applied in improving load modeling accuracy by considering the most recent consumption information after the change.

General information
State: Published
Ministry of Education publication type: A4 Article in a conference publication
Authors: Chen, T., Mutanen, A., Järventausta, P., Koivisto, H.
Number of pages: 6
Pages: 202-207
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Host publication information
ISBN (Print): 9781479976959
Keywords: AMR, Change detection, clustering
DOIs:
10.1109/PTC.2015.7232269

Bibliographical note
ORG=dee,0.75
ORG=ase,0.25
Monetary impact of dynamic pricing and demand response on households: The winners and losers

Smart grid paradigm is hailed as the Holy Grail to manage the future electricity consumption in a sustainable manner, and demand response (DR) is a fundamental component in the realization of smart grids. However, DR requires active household participation and in the previous studies monetary benefit is identified as the main motivation for the households to participate. In this paper, we analyze DR on households in terms of the monetary impact. Smart meter data together with data about properties of households are used from 669 households. Dynamic pricing schema and DR model are proposed and utilized in simulations. Self-Organizing Maps (SOM) are applied to identify the household segments that are monetarily affected in the simulations.

A communication based protection system for solving DG related protection challenges

This paper presents a communication based protection automation system which is designed for solving DG related protection problems. The system is able to tackle problems related protection blinding, nuisance tripping of feeders and generators and problems related to unintentional islanding. Moreover, the system can be configured to allow low voltage ride-through without compromising loss of mains protection. However, the system also has the potential of enhancing the reliability of electricity distribution service to DG units by automatically switching an alternative feeding path if the original feeding route is faulted.

Demonstration of the Inter-Organizational Situation Awareness System to Major Disturbances

There have been several problems in information exchange between organizations in the disturbances of the electricity supply. For instance, in Finland one municipality had problems to reach their local DSO (Distribution System Operator)
during a disturbance in 2011. They had only the phone number of the DSO’s customer service, which was congested. Usually in disturbances, municipalities and authorities receive information from DSOs’ web pages, like transformer level maps or lists that show the outages and their duration, and by phone conversations. In general, it can be said that the inter-organizational situation awareness in disturbance situations is needed. After the storms in Finland in December 2011 the Finnish Electricity Market act was changed so that DSOs should participate in the formation of situation awareness and supply any information relevant to this purpose to the responsible authorities.

The paper presents a demonstration of the interorganizational situation awareness system developed in this research. The demonstration consists of an internet service which combines information about disturbances in the electricity supply from DSOs’ information systems and information from other actors. The demonstration illustrates how the exchange of information between actors can be executed by using a situation awareness system. It extends the integration of DMS (Distribution Management System) in an unusual direction by taking the other actors into account.

**Implementation Possibilities of Power-based Distribution Tariff by Using Smart Metering Technology**

This paper discusses on the implementation possibilities of distribution tariffs that include a separate demand (i.e. power) component for small customers by taking use of the present, and still developing, smart metering technology. Power-based distribution tariffs offer the customers effective price signals and better possibilities to affect to the size of their distribution fees through their own actions. The use of demand based components in the tariff structures also reflects the actual cost structure of the Distribution System Operator (DSO) and could make the pricing of the DSOs more just and transparent. In the paper, the possibility of limiting the yearly peak hourly power demand of the customer with the software fuse functionality of the smart meters is in a key role when different ways of implementing power based distribution tariff are studied. The paper also provides information about results of a questionnaire made to smart metering technology vendors about the present state and technological possibilities of the smart meters e.g. in the case of load control possibilities.

**Modelling of simultaneous fault to reliability enhancement in distribution system**

The main purpose of an electric power system is to provide electricity from the generation source to the customer point. Security and adequacy are the two most important requirements in power system reliability. As most of the faults that happen in a distribution network are experienced by the customers, improving the security of the distribution side can have
a beneficial effect on the entire network. Faults can occur singly, but multiple faults can occur at the same time in many different places in the network. It is these simultaneous faults that can drastically affect the security of a network, and directly decrease its reliability. This paper studied the modelling of simultaneous faults by using the Monte-Carlo (MC) algorithm in a distribution network. This makes it possible to evaluate the effect of the repair time in different situations, and also to model various solutions to enhance the reliability of the network. A real overhead line feeder in a distribution network from a rural electricity distribution company was chosen for modelling the MC algorithm and to study the reliability procedures based on it. The calculations in our simulation model are based on number of the faults and the availability of maintenance and repair crews in the case of simultaneous faults. The algorithm can also be used for calculating the reliability indices in radial and mesh configurations with radially operated feeders.

**General information**

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Organisations: Department of Electrical Engineering, Research area: Power engineering  
Authors: Dehghani, N., Supponen, A., Repo, S.  
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**Host publication information**

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**Publication series**

Name: International Conference and Exhibition on Electricity Distribution  
ISSN (Electronic): 2032-9644  
Links:  
Research output: Scientific - peer-review » Conference contribution

**Novel Sensor Solutions for On-Line PD Monitoring**

The electric utility industry is going through significant changes caused by new regulation models, distributed generation, increased competition and requirements for continuous improvement in the quality of power supplied to the customers. To minimize outages and supply interruptions, utilities must be able to monitor and locate faults more quickly and to develop condition monitoring in a more preventive direction. On-line continuous partial discharge (PD) measurement is an excellent way to determine the overall health of the medium voltage (MV) cables. Essential parts of a PD monitoring system are the sensors for measuring the high frequency PD signal. The continuous on-line PD monitoring of MV cables is a problem, primarily because no adequate cost-effective sensor solution is available for permanent installation. The goal of this paper is to develop a low-cost, sensitive and robust sensor solution for continuous on-line PD monitoring of MV underground cable networks.

**General information**

State: Published  
Ministry of Education publication type: A4 Article in a conference publication  
Organisations: Department of Electrical Engineering, Research area: Power engineering  
Authors: Siddiqui, B., Pakonen, P., Verho, P.  
Number of pages: 5  
Pages: 1-5  
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Title of host publication: 23rd International Conference on Electricity Distribution, CIRED 2015  
Article number: 1200

**Publication series**

Name: International Conference and Exhibition on Electricity Distribution  
ISSN (Electronic): 2032-9644  
Links:  
Research output: Scientific - peer-review » Conference contribution

**Practical Implementation of Demand Response in Finland**

In this paper, we have studied the potential, incentives, and obstacles of the practical implementation of the demand response (DR) in Finland. We have discovered that there are remarkable amount of the controllable loads, which can be controlled via smart meters. Furthermore, market places for DR already exists, and it is possible to gain economic benefits from DR. However, the roles and responsibilities of the stakeholders are unclear, and heterogeneity in systems and solutions hinder the actualization of the load controls. Furthermore, there may appear conflicting interests, as the sharing of the costs and benefits seem to be unequal in some cases, and contradicting needs for load controls between stakeholders may occur. As solutions to overcome the discovered obstacles, we suggest that more standardization to
interfaces between stakeholders' ICT systems is needed, stakeholders’ roles and responsibilities in the demand response process need to be clarified, and modifications in regulations are needed, to ease the problems concerning missing incentives and the conflict of interests.

**General information**
State: Published
Ministry of Education publication type: A4 Article in a conference publication
Organisations: Department of Electrical Engineering, Research area: Power engineering, Lappeenranta University of Technology, Tampere University of Technology, Tampere University of Applied Science
Authors: Honkapuro, S., Tuunanen, J., Valtonen, P., Partanen, J., Järventausta, P., Heljo, J., Harsia, P.
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Title of host publication: 23rd International Conference and Exhibition on Electricity Distribution, CIRED 2015
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**Reserve Power – Alternative Solution to the Network Investments in Rural Area Networks?**
The new legislative requirements and all the time tightening economic regulation cause a great pressure for Finnish distribution system operators to improve the security of power supply. Underground cabling has been seen in many cases basically the only but at the same time very expensive solution to solve this problem. This paper presents that with the help of reserve power solutions it is possible to fulfill the requirements especially in sparsely populated rural areas. The results show the profitability of utilizing reserve power generators instead of investing in the cabled network. In addition, the calculations support the fact that customers should at least consider purchasing own reserve power.

**General information**
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Organisations: Department of Electrical Engineering, Research area: Power engineering
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**A novel VSC-HVDC link model for dynamic power system simulations**
This paper introduces a new RMS model of the VSC-HVDC link. The model is useful for assessing the steady-state and dynamic responses of large power systems with embedded back-to-back and point-to-point VSC-HVDC links. The VSC-HVDC model comprises two voltage source converters (VSC) linked by a DC cable. Each VSC is modelled as an ideal phase-shifting transformer whose primary and secondary windings correspond, in a notional sense, to the AC and DC buses of the VSC. The magnitude and phase angle of the ideal phase-shifting transformer represent the amplitude modulation ratio and the phase shift that exists in a PWM converter to enable either generation or absorption of reactive power purely by electronic processing of the voltage and current waveforms within the VSC. The mathematical model is formulated in such a way that the back-to-back VSC-HVDC model is realized by simply setting the DC cable resistance to zero in the point-to-point VSC-HVDC model. The Newton-Raphson method is used to solve the nonlinear algebraic and discretised differential equations arising from the VSC-HVDC, synchronous generators and the power grid, in a unified frame-of-reference for efficient, iterative solutions at each time step. The dynamic response of the VSC-HVDC model is assessed thoroughly; it is validated against the response of a detailed EMT-type model using Simulink®. The solution of a relatively large power system shows the ability of the new dynamic model to carry out large-scale power system simulations with high efficiency.
Demand Side Management in Open Electricity Markets from Retailer Viewpoint

In this paper, we have evaluated the incentives and obstacles of the demand side management (DSM) from the viewpoint of the electricity retailers. Research results are based on the questionnaires, workshops, and simulations. Based on our studies, it seems that there exist remarkable amount of controllable loads, and also market places for flexible resources have already been established in Finland. Furthermore, it seems that the economic profitability of the DSM is significantly higher, if resources are utilized in reserve or balancing power markets, instead of the day-ahead spot-markets. However, heterogeneity in stakeholders’ solutions and systems hinder the possibility to control customers’ loads based on the demands of the market places. Moreover, the roles of the stakeholders are unclear, and conflicts of interests seem to exist between the stakeholders.
Product level accelerated reliability testing of motor drives with input power interruptions

Motor drives utilizing power semiconductors play an important role in modern day electric motor control. Although the reliability of power semiconductors is widely studied, the product level reliability of motor drives has been studied markedly less even though their more complex control and measuring electronics often make them more vulnerable to environmental stresses. In order to advance product level accelerated reliability testing, customized test methods with multiple simultaneous or sequential stresses can be used. However, the knowledge of combined effects of different stresses is still largely unknown. In this research the reliability of a commercial motor drive was studied. Environmental conditions used included an 85 °C constant temperature test and an 85 °C test with 85% relative humidity. Additionally, input power interruptions were included to study the effect of sudden shortages of electricity. The results of the study showed that the mean time to failure for the devices tested with the input power interruptions was notably shorter than that for the test series without them. An especially clear effect of the input power interruptions was seen on the power MOSFETs of the motor drives. Moreover, the humidity was found to play an important role in the reliability of the motor drives.
Role of public regulators in demand response business ecosystem - Case New York State electric power market

This paper draws on business ecosystem research and concepts to study the structure and interdependencies of demand response business network in New York State power market, with a particular focus in investigating the role of public regulators in the business ecosystem. The analysis suggests that while demand response aggregators operatively lead the ecosystem, the regulators hold a central role in both the birth and sustainability of the ecosystem through their authority in setting market rules and performance requirements as well as in their control of the demand response program funding mechanisms. Moreover, an analysis of the distribution of economic value generated by the ecosystem indicates that only a minimal portion of the value surplus accumulates to the ecosystem's operative customers (NYISO and utilities), which suggests that they may have only limited incentives to support the growth and sustainability of the business ecosystem.

General information
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Ministry of Education publication type: A4 Article in a conference publication
Organisations: Department of Electrical Engineering, Research area: Power engineering, Department of Industrial Management, Research group: Center for Innovation and Technology Research, Managing digital industrial transformation (mDIT), Smart Energy Systems (SES)
Authors: Koivisto, V., Järventausta, P., Mäkinen, S.
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DOIs: 10.1109/EEM.2015.7216610

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ORG=tta,0.33
Source: Bibtex
Source-ID: urn:b7f3d8315db2683f0940fe2462ec4fd5
Research output: Scientific - peer-review › Conference contribution

Comprehensive dynamic analysis of photovoltaic generator interfacing DC-DC boost power stage

In transformer-less grid-connected renewable energy systems, interfacing of photovoltaic (PV) generators is typically implemented by means of DC-DC boost-power-stage converter, mainly because of its voltage-boosting capability. In order to track the maximum power point of a PV generator, input voltage of the converter is usually feedback controlled, forcing the converter to operate as a current-sourced rather than voltage-sourced converter. Nevertheless, PV generator interfacing power stage is commonly assumed to possess the same dynamic properties as corresponding voltage-sourced power stage. Investigations presented in this study reveal explicitly that the dynamics of PV generator interfacing DC-DC boost power stage resembles conventional buck power stage behaviour with duty-cycle independent resonance and additional right-half-plane zeros. In addition, the duty cycle has to be decreased for increasing the corresponding output variables (i.e. input voltage and output current). Extended experimental results are given to support the theoretical findings.

General information
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Ministry of Education publication type: A1 Journal article-refereed
Organisations: Department of Electrical Engineering, Research area: Power engineering, Smart Energy Systems (SES), Ariel Univ, Dept Elect Engn & Elect, Hybrid Energy Sources Lab
Authors: Viinamäki, J., Jokipii, J., Messo, T., Suntio, T., Sitbon, M., Kuperman, A.
Number of pages: 9
Matlab/Simulink modeling to study the effect of partially shaded condition on photovoltaic array's maximum power point

General information
State: Published
Ministry of Education publication type: A1 Journal article-refereed
Organisations: Department of Electrical Engineering, Research area: Power engineering, Islamic University of Gaza
Authors: Matter, K., El-Khozondar, H., El-Khozondar, R., Suntio, T.
Number of pages: 7
Pages: 697-703
Publication date: May 2015
Peer-reviewed: Yes

Publication information
Journal: International Research Journal of Engineering and Technology
Volume: 02
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Original language: English
Links:
Research output: Scientific - peer-review › Article

A Finite Element Simulation Tool for Predicting Hysteresis Losses in Superconductors Using an H-Oriented Formulation with Cohomology Basis Functions
Currently, modelling hysteresis losses in superconductors is most often based on the H-formulation of the eddy current model (ECM) solved using the finite element method (FEM). In the H-formulation, the problem is expressed using the magnetic field intensity H and discretized using edge elements in the whole domain. Even though this approach is well established, it uses unnecessary degrees of freedom (DOFs) and introduces modelling error such as currents flowing in air regions due to finite air resistivity. In this paper, we present a modelling tool utilizing another H-oriented formulation of the ECM, making use of cohomology of the air regions. We constrain the net currents through the conductors by fixing the DOFs related to the so-called cohomology basis functions. As air regions will be truly non-conducting, DOFs and running...
times of these nonlinear simulations are reduced significantly as compared to the classical H-formulation. This fact is demonstrated through numerical simulations.

**General information**

State: Published
Ministry of Education publication type: A1 Journal article-refereed
Organisations: Department of Electrical Engineering, Research area: Electromagnetics, Microsoft Research Cambridge, UK, École Polytechnique de Montréal
Authors: Lahtinen, V., Stenvall, A., Sirois, F., Pellikka, M.
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**DOIs**: 10.1007/s10948-015-3074-x

**Evolving Smart Meter Data Driven Model for Short-Term Forecasting of Electric loads**

Short-term forecasting of electric loads is an essential function required by Smart Grids. Today increasing amount of smart metering data is available enabling the development of more accurate and adaptive data-driven models for short-term load forecasting. Until now, a plethora of models have been developed ranging from simple statistical regression models to more advanced models such as artificial neural networks (ANNs) and support vector machines (SVMs). Despite the relatively high accuracy obtained, data-driven models are still perceived to be highly complex and nontransparent, thus not allowing engineers and system operators to interpret and understand properly their behavior. Therefore it is important to develop optimization schemes, which can be used to facilitate the selection of appropriate data-driven model structure, and thus improve the acceptance of data-driven models in the domain. This study presents an optimization scheme based on multi-objective genetic algorithm (GA) for designing simple but accurate data-driven models for short-term forecasting of electric loads using smart metering data. The optimization scheme is demonstrated for an ANN model, and the performance of the resulting ANN model is assessed in terms of several performance indices.
Dynamics of photovoltaic-generator-interfacing voltage-controlled buck power stage

This paper investigates the dynamic properties of the photovoltaic-generator-interfacing voltage-controlled buck power stage operating in both the maximum and limited power point tracking modes. The photovoltaic generator (PVG) is known to possess both current- and voltage-source properties with respect to its maximum power point. While voltage-fed operation is conventional, current-fed action is nontrivial and is thoroughly analyzed in this paper. The photovoltaic-generator-interfacing converter is formed by adding a capacitor at conventional voltage-fed converter input terminals, turning it into a current-fed power stage. During the maximum power point tracking phase, converter input voltage is regulated, possessing nontrivial dynamics. The situation is burdened further when output-voltage control should be alternatively realized to limit the voltage of the converter terminating the energy storage element. It is shown that both the photovoltaic generator and the terminating energy storage greatly affect the combined system dynamics. Parallel as well as cascaded control arrangements are proposed to support dual-mode system operation. Extended experimental results are shown to enforce presented theory and reveal nontrivial dynamics-related issues.
Driving pattern analysis of Nordic region based on National Travel Surveys for electric vehicle integration

Electric vehicles (EVs) show great potential to cope with the intermittency of renewable energy sources (RES) and provide demand side flexibility required by the smart grid. Furthermore, EVs will increase the electricity consumption. Large scale integration of EVs will probably have substantial impacts on power systems. This paper presents a methodology to transform driving behavior of person into one of the cars in order to analyze the driving pattern of EVs based on the National Travel Surveys. In the proposed methodology, a statistical process is used to obtain the driving behavior of cars by grouping the survey respondents according to the driving license number and car number, and mapping the households with similar characteristics. The proposed methodology was used to carry out the driving pattern analysis in the Nordic region. The detailed driving requirements and charging/discharging availability of vehicles along the day were obtained. Two types of EV availabilities were studied in this paper considering different charging/discharging conditions of EVs for the power system integration, i.e. EV availability all day and EV availability at home. The results show that the daily driving requirements of the Nordic region are not very intensive. The driving patterns of vehicles in the Nordic region vary on weekdays and weekends. The two types of EV availabilities are quite different from each other.

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Research output: Scientific - peer-review › Article

An accurate small-signal model of a three-phase VSI-based photovoltaic inverter with LCL-filter

Three-phase photovoltaic inverters are usually equipped with an LCL-type output filter to reduce cost and size of the converter compared to a simple L-type output filter. The LCL-filter has an inherent resonance which has to be damped by a passive or active method to avoid instability. This paper presents an accurate full-order small-signal model of the three-phase VSI-based photovoltaic inverter with LCL-type output filter. The model is developed in the dq-domain, where the steady-state operating point can be solved. The developed small-signal model has been verified by extracting frequency responses from a scaled-down prototype. The model is shown to give accurate predictions on the shape of inverter transfer functions such as control loop gains and output impedance. Thus, the model can be used for control design, impedance shaping and impedance-based stability analysis.

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Organisations: Department of Electrical Engineering, Research area: Power engineering, Smart Energy Systems (SES)
Authors: Aapro, A., Messo, T., Suntio, T.
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Appearance of a Drift Problem in Variable-step Perturbative MPPT Algorithms

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Closure to Discussion on "Effect of Multilevel Inverter Supply on Core Losses in Magnetic Materials and Electrical Machines"

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Scopus rating (2008): SJR 2.43 SNIP 2.919
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Designing Inter-Organizational SA System to Disturbances of Electricity Supply

There have been several problems in information exchange between actors in the disturbances of electricity supply. For example, in storm 2011 in Finland, a municipality had problem to contact their local distribution system operator (DSO).
because they had only the phone number of DSO’s customer service, which was congested.

At present, the situation awareness in disturbances of electricity supply is focused on every actors own perspective. In addition, present sources of SA are shattered.

In this research, the demonstration of inter-organizational situation awareness system to disturbances of electricity supply is developed.

The design process has been iterative. The usability of the first version of the demonstration has been evaluated with Nielsen’s heuristic evaluation method. The needs of information exchange have been studied by user need interviews with one municipality and two fire and rescue service.

The theory of team SA is inadequate in case of disturbances of electricity supply. Different actors do not have common sub-goals. There is a need for extension of the team SA theory to cover cases where sub-goals are more likely linked to each other than common.

The designed demonstration improves information exchange between actors. In addition, it improves the resilience of society in disturbances by helping the authorities to focus their actions to sites that do not have electricity and or mobile network.

The main difference that the demonstration has to existing methods is that there is a criticality database where information about sites that are highly dependent on electricity is stored. In addition, the demonstration combines information from multiple different actors to same view.

In this research it was clarified that inter-organizational situation awareness system can change the thinking about how the restoration process of electricity distribution network in disturbances should be formed.

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**Dielectric Breakdown Strength of Thermally Sprayed Ceramic Coatings: Effects of Different Test Arrangements**

Dielectric properties (e.g., DC resistivity and dielectric breakdown strength) of insulating thermally sprayed ceramic coatings differ depending on the form of electrical stress, ambient conditions, and aging of the coating, however, the test arrangements may also have a remarkable effect on the properties. In this paper, the breakdown strength of high velocity oxygen fuel-sprayed alumina coating was studied using six different test arrangements at room conditions in order to study the effects of different test and electrode arrangements on the breakdown behavior. In general, it was shown that test arrangements have a considerable influence on the results. Based on the results, the recommended testing method is to use embedded electrodes between the voltage electrode and the coating at least in DC tests to ensure a good contact with the surface. With and without embedded electrodes, the DBS was 31.7 and 41.8 V/µm, respectively. Under AC excitation, a rather good contact with the sample surface is, anyhow, in most cases acquired by a rather high partial discharge activity and no embedded electrodes are necessarily needed (DBS 29.2 V/µm). However, immersion of the sample in oil should strongly be avoided because the oil penetrates quickly into the coating affecting the DBS (81.2 V/µm).

**General information**

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Organisations: Department of Electrical Engineering, Research area: Power engineering, Smart Energy Systems (SES), VTT Technical Research Centre of Finland
Interfacing renewable energy sources for maximum power transfer-Part II: Dynamics
The manuscript reveals combined source-converter-load dynamics of interfacing renewable energy generators by means of terminal voltage control, aimed to track a Maximum Power Line. Control-to-input voltage transfer functions are calculated for three basic DC-DC converters based power electronic interfaces operating in both current and voltage control modes; respective stability assessment is performed as well for each arrangement. In order to generalize the derived dynamics, it is shown that photovoltaic and wind generators may be represented by similar electrical equivalent circuits, possessing comparable small-signal dynamics. It is exposed that dynamic impedance of renewable energy generators is both operating point and environmental conditions dependent and hence plays a crucial role in the combined source-converter-load dynamics from affecting system damping to causing open-loop instability in particular arrangements. Consequently, special care must be taken when designing power electronic interface intended to operate as a renewable energy generator power processor while at the same time the controller must be robust enough to ensure system stability for all expected environmental conditions. In addition, in case fixed closed-loop behavior is required through the whole operating range of the system, some kind of adaptive mechanism is required to estimate the dynamic impedance online. Several particular case examples of the proposed method presented in the literature are reviewed.
Kysynnän jousto - Suomeen soveltuvat käytännön ratkaisut ja vaikutukset verkkoyhtiölle (DR pooli): Loppuraportti


Ilmastonmuutoksen hidastamiseen on taustalla myös uusissa rakentamiseen liittyvissä energiatehokkuusmääräyksissä, joiden tavoitteena on ohjata rakentamista yhä energiatehokkaampaan ja uusiutuvia energialähteitä hyödyntäävään suuntaan. Energiatehokkuutta arvioitavissa tulee kiinnittää aikaisemmin enemmän huomiota myös metalleriintä tehohuippujen ja käyttöprofiileihin. Kysynnän jousto tarve ja tavoitteet tulee nähdä myös tarpeellisena osana tulevassa lähis nollaenergia eli nZEB-rakentamisessa.

Kysynnän jousto sisältää laajan joukon erilaisia toimintoja, joiden merkitys, tarve ja ansaintalogiikka vaihtelevat toimijan näkökulmasta. Kysynnän joustollista voidaan ymmärtää täällä esimerkiksi hilluettelurakenteita toteutettava vaikuttaa asiakkaan käyttäytymiseen, vaihtelevaan energian hintaan pohjautuvat suorat ohjaustoinniperusteet sekä siirto- ja joukerkuvun tarpeista tulevat ohjaukset, kuten, kuorma, toimintokesken kantavarkkoyhtiön reservin tai yhteen mykset kykyakin kuorman porrastaminen. Seuraavassa on kuvattu lyhyesti kysynnän jouston mahdollisuuksia ja tarpeita eri toimijoiden näkökulmasta:

- Kantavarkkoyhtiölle kysynnän jousto tarjoaa mahdollisuuksia tehotasapainon hallintaan ja taaajuuden säätöön käyttö- ja häiriöreservien osalta sekä mahdollisesti myös kaukasuutta tehopolu-tulosten hallintaan.

- Sähkön vähittäismyyjä voi hyödyntää kysynnän joustoa sähkön hankinnan suunnitteluissa, tasevastaavana oman taseensa hallinnassa muiden toimenpiteiden rinnalla, säätö- ja markkinoiden tarjojouksissa sekä uusien tuotteiden ja liiketoiminnan kehittämisessä.
- Jakeluvirkkohtioi voi hyödyntää kysynnän jouston mahdollisuuksia pitkän aikavälin verkon suunnittelussa verkon mitoitustehon näkökulmasta sekä reaalialaisessa käyttötoiminnassa esim. poikkeustilanteiden aikaisen huiputehon hallinnassa.

- Sähkön loppukäyttäjän näkökulmasta kysynnän jousto mahdollistaa mm. sähkön käytön edullisen hinnan aikana, ostosähkön vähentämisen, oman pientuotannon täysimääräisen hyödyntämisen, huiputehojen pienentämisen sekä mahdollisesti liittymäkoon rajoittamisen.

- Laite- ja järjestelmätoimittajille sekä palvelun tarjoajille (esim. kuormia aggregoiva "jousto- operaattori") kysynnän jousto tarjoaa uusia tuotto- ja liiketoimintamahdollisuuksia.

Kysynnän jouston laajamittainen hyödyntäminen edellyttää eri toimijoiden välistä yhteistyötä. Etätiluetat legiammittarit (AMR, Automated Meter Reading), joiden osalta Suomi on edelläkävijä maailmanlaajuisesti, mahdollistavat todelliseen tuntikulutukseen pohjaantuva taseeselvityksen sekä vähätäsmarkkinoille uusia tuotinhuinnollisuuden perustuvia hinnottelumalleja. Nämä puolestaan mahdollistavat asiakkaan osallistumisen kysynnän joustoon tuntimarkkinoille. Lisäksi etätiluentajärjestelmä käyttetään jo tänä päivänä kuormien ohjaamiseen asiakkaan käytössä olevien tarrifien mukaisesti (esim. yö-/päiväähkösähkö).

Olemassa olevaa AMR-infrastruktūria on kansantaloudellisessa mieleessä järkevää käyttää myös suoraan kuorman ohjaamiseen siinä määrin kuin asennettu infrastruktuuri sen mahdollistaa.

Kysynnän jousto potentiaali tarkasteltiin energian kulutuksen ja tyyppillisimmän laitetehojen lähtökohdista. Vuodenajasta, vuorokaudesta ja vuorokauden tunnista riippuen potentiaalit vaihtelevat voimakkaasti. Suurimmat ohjauspotentiaalit ovat lämmityskaudella sähkölämmityksen sekä käyttöveden lämmityksessä läpi vuoden. Mahdollisuuksia on myös isompien kiinteistöjen ilmanvaihdon, jäähydytysten ja valaistuksen ohjaamiseen sekä mm. ulkovalaistuksessa, autolämmityksissä, erilaisissa lisälämmitysvastuksissa sekä erikoiskohteissa, kuten kasvihuoneet.

Tehtyjen analyysien ja verkkojärjestelmiöiden tehdyn kyselyn perusteella AMR-mittareiden ohjausaikatason kytketyn ohjausreleen kautta on ohjattavassa yli 1 000 MW pääosin erilaista sähkölämmitys- ja lämmiväesiavaraa ja samouda. Tämän ohjattavissa oleva kuormitus olisi otettavissa käyttöön hiipyynkin nopeassa, ja hyödyntettävissä esim. day-ahead (Elspot) - markkinoilla toimittajissa. Käytännön toteutus vaatii kuitenkin vielä tietojärjestelmiä ja läänetarkisteita standardointia siihen, että ohjaussignaatteet olisi saa saada saamaan sähkömyyjien ja verkkojärjestelmien välillä. AMR-mittareiden ns. kuormanohjausreleeseen on kytkettyynä samansuuruudessa oleva määrä ohjattavaa kuormaa, jota voitaisiin hyödyntää päivän sisällä tapahtuvissa ohjausajoihin (intra-day (Elbas), säätöahk_TMERA markkina). Riittävän nopean ja luotettavan tiedonsiirtoon sekä mittareiden ja keskusten asennuksiin liitty jäähydysten ja sähkölämmityksen ohjaamiseen verrattuna enemmän teknisiä haasteita. Jakeluvirkkohtien valvontamallin, esim. innovaatiokannustimen muodossa, tulee käsitellä ohjaamista, että se luo kannusteita verkkojärjestelmiöille edistää AMR-mittareiden kautta ohjattavissa olevan ohjauspotentiaalin täysimääräistä hyödyntämistä.


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Sähkön myyjän näkökulmasta Day-ahead tai intra-day markkinoihin tai tasehallintaan liittyvällä kysynnän joustolla saavutettavien taloudellisten hyödyntysten realisoitumisessa edustuttaa se, että kysynnän jousto toteutuksen vaikuttavissa infrastruktuurissa on lähempi valmiina. Sähkömarkkinoiden näkökulmasta sekä reaaliaikaisessa käyttötoiminnassa esim. poikkeustilanteiden aikaisen huiputehon hallinnassa.

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Isompien kiinteistöjen (palvelu-, liike ja toimistorakennukset) ohjaamisesta käytetään erilaisia mittareita ja täysin automatisoitunutta ohjaamista. Isompien kiinteistöjen ohjaamisesta on nykyään tärkeää käyttää AMR-mittareiden ohjauskuvioita, jotta joustavuutta ja tehokkuutta voidaan saavutella. Isompien kiinteistöjen ohjaamisesta on nykyään tärkeää käyttää AMR-mittareiden ohjauskuvioita, jotta joustavuutta ja tehokkuutta voidaan saavutella.
ohjauksella saavutettava hyöty ei eliminoidu verkon kapasiteettitarpeen kasvamisena ja siten asiakkaiden korkeampina siirtomaksuina.

Keskeistä kysynnän jouston laajamittaiselle hyödyntämiselle on muodostaa kokonaisvaltainen näkemys kysynnän jouston toiminnallisuudesta ja eri toimijoiden mahdollisesti ristikkäisistäkin rooleista, kaikkien toimijoiden liiketoimintaa tukevasta markkinamallista, tiedonsiirtoarajapintojen yhteensovittamisesta sekä kysynnän joustoa edistävän lainsäädännön kehittämisestä. Erityisesti kysyntäjouston ansaantäiloja vaatii kehittämistä, asiakkaiden ymmärrystä tulee lisätä ja asiakkaille tulee tarjota kannustetut kysynnän joustoon osallistumiseen. Kuorman ohjauksen käyttöönotto edellyttää myös uusien ja uusittavien kiinteistöjen sähköverkon ja laitevalintojen suunnittelun tavoitteellista ohjausta. Lainsäädäntöön liittyvien kysymysten lisäksi keskeisiä esteitä kysynnän joustoon toteutumiselle yleisesti ovat hajanainen toimialakenttä (suuri määrä erilaisia toimijoita), standardoimattomat prosessit, tietojärjestelmien rajapinnat ja toimintavasteiden suuri hajonta, sekä asiakkaiden suurimman ohjattavuuslähtöön puuttuminen.

Tutkimusprojektin lopputuloksena esitetään lukuisa joukko toimenpiteitä, joilla voidaan edesauttaa laajamittaisen kysynnän jouston yleistymistä. Vastuu toimenpiteistä jakautuu laajasti toimialoihin (mm. sähkömyyjät ja verkkoyhtiöt), toimialojen järjestjien edustajille sekä viranomaisille. Toimenpiteet liittyvät:

- kysynnän jouston tuotteistamiseen sähkön myyjän ja jakeluverkkojärjestön toimintojen osalta,
- ehdotettaville informointiin ja koulutukseen,
- toimintatapojen yhtenäistämiseen toimintaprosessien sekä teknisten järjestelmien osalta,
- lainsäädännön, viranomaismääräyksen ja ohjaiden kehittämiseen, joihin sisältyy erityisesti verkkoliiketoiminnan valvontamallin ja rakennusmääräyksen kehittäminen.

Vaikka kysynnän jouston laajamittainen käyttöönotto edellyttää vielä paljon erilaisia toimenpiteitä, niin olemassa oleva infrastruktuuri ja markkinapaikat sekä meneillään oleva kehitystö tuo uskoa kysynnän jouston laajamittaisen toteutuksen käynnistymiselle lähitulevaisuudessa.

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On the Provision of Frequency Regulation in Low Inertia AC Grids Using HVDC Systems

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Organisations: Department of Electrical Engineering, Research area: Power engineering, Smart Energy Systems (SES), Universidad Nacional Autónoma de México
Authors: Castro Gonzalez, L. M., Acha Daza, E.
Principles of designing for situation awareness

High level of situation awareness is a key factor in many domains to ensure correct decision making and actions. Situation awareness has been studied extensively in the aviation and military domains but the research also applies to other domains e.g. power grid operations and managing disturbances of electricity supply. Based on the research design principles have been created in order to help system designers to create better user interfaces for systems used in operational activities. These principles have been applied when designing the situation awareness system concept for managing disturbances of electricity supply.

Single-source multi-battery solar charger: Analysis and stability issues

In this paper, dynamic analysis of a multi-battery dual mode charger, powered by a single solar array and suitable for lead-acid and lithium-ion cell-based batteries is presented. Each battery is interfaced to the solar array by means of a current-controlled buck power stage, operating either in constant power or constant voltage mode. Operation in former/latter charging mode implies regulating input/output voltage of the converter, which is a non-trivial situation since while feeding different batteries, all the converters share the same input terminals, connected to the solar array. It is revealed that when at least one of the batteries operates in constant power charging mode, open-loop instability occurs whenever converter input voltage is lower than maximum power point voltage of the solar array. Consequently, input voltage regulating controller must be designed to stabilize closed-loop dynamics for the worst case of instability, which is also derived. Moreover, it is shown that the dynamics of the converters operating under output voltage control are perceived as disturbances by input voltage control loop and must be properly rejected. Simple loop shaping design is proposed based on a PI controller, allowing stabilizing the system in case of worst case instability and rejecting output voltage control induced disturbances at the expense of non-constant, operating-point dependent closed-loop damping.
Smart Grids with Large-Scale Implementation of Automatic Meter Reading: Experiences from Finland

Finland is a forerunner in large-scale AMR (automated meter reading, known also as smart metering) roll-out worldwide, not only in coverage of installations, but also in functionality and utilization of AMR system in various business processes. In 2009, the Finnish Government passed a new act, which states that at least 80% of the customers of each distribution system operator (DSO) must have AMR implemented by 31 December 2013. In practice, almost all customers are provided by a new AMR meter. The law requires the AMR meter that features hourly energy measurement and registrations of quality of supply-and-demand response functionality. AMR system installation is not only energy remote reading, but it enables real-time two-way communication between customers and other actors and offers huge amount of data for developing new functions for smart grids. The use of AMR data in various functions increases cost effectiveness of AMR investments. AMR system with relating ICT (information and communications technology) systems and business processes forms a larger entity to create added value for customers, DSO, energy retailer, and service providers. AMR is an enabler of competition in electricity market for enhancing flexible change of energy retailer. Hourly measurements enable new kind of dynamic tariffs that support energy-efficient targets and operation of electricity market. Using hourly measurements, more accurate and even customer-specific load models can be created to support load estimation and forecasting. By integrating AMR system with SCADA (supervisory control and data acquisition) system and DMS (distribution management system), network management can be enlarged also to cover low voltage networks, for example, for automatic indication of burnt fuse. AMR system enables also new functions for customer service, for example, as web-based applications for the end customers. Household-level loads now in time-of-use control can also be dynamically controlled by electricity retailers via AMR systems.

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Authors: Jarventausta, P.
Publication date: 2015

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MO Surge Arresters Stresses and Test Procedures: CIGRE Technical Brochure, WG A3.17

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