Modeling of load-transient response of direct-duty-ratio-controlled buck converter

This paper provides a simple analytical model for the closed-loop output impedance of a direct-duty-ratio-controlled buck converter, which can be used to predict the behavior of the output voltage during a load-current transient. The modeling method utilizes standard control theory to obtain the model for the sensitivity function based on the crossover frequency and phase margin of the output-voltage feedback loop as well as on a clever estimate for the corresponding open-loop output impedance. The modeling method is validated by means of simulations and experimental tests.

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.
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.

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Ministry of Education publication type: A4 Article in a conference publication
Organisations: Electrical Energy Engineering, Research area: Power engineering, Research group: High voltage engineering, University of Bologna, Italy, VTT Technical Research Centre of Finland
Authors: Montanari, G. C., Seri, P., Karttunen, M., Paajanen, M., Lahti, K., Rytöluoto, I.
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Research output: Scientific - peer-review » Conference contribution

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

General information
State: Published
Analysis of Transition Steps Towards Power-based Distribution Tariff of Small Customers

This paper discusses the development of distribution tariffs of small customers. Future changes in the electricity sector challenge the present distribution tariff structures and instead of a passive approach, the Distribution System Operators (DSO) have the opportunity to respond to the challenges by applying novel tariff structures. The movement towards Power-based Distribution Tariffs (PBDT) has been seen as a very potential development direction. However, before implementing PBDTs, or any other novel tariff structures, it has to be ensured that the change will not cause unwanted outcomes such as too aggressive an impact on the distribution fees of the customers or on the total revenue of the DSO. The main focus of this paper is on the transition viewpoints from present tariffs towards one selected PBDT structure.

Cost-benefit Analysis for Using the Li-ion Batteries in Low-voltage Network for Decreasing the Outage Time Experienced by Customers

Battery energy storage (BES) installed in the low-voltage busbar of a secondary substation can prevent part of the customers’ interruptions in a low voltage (LV) network that would happen due to failures in the supplying medium voltage (MV) network or rarely in the high voltage network (HV). In fact, over 80% of average customer outage time comes from the interruptions in the MV network [1]. One way to improve the network reliability for decreasing the interruption time of customers is to focus the investments on the MV network (e.g. network automation or cabling). The other option is to develop local solutions at LV network level by energy storages.

This study compares the life-time costs of Li-ion batteries against the benefits achieved by decreasing the customer interruption costs (CIC) defined by the Finnish network business regulation model. The analysis is done by using the interruption and network data of Elenia Oy consisting of 13,867 LV networks in rural areas. The results indicate profitability in the interruption prone LV networks.
Development of Power-based Tariff Structure for Small Customers and Pathway for This Change

This paper discusses the development of alternative power-based tariff structures for small customers and presents a pathway for adapting one new structure. Development of new tariff structures are needed when actively responding to the future changes in the operating environment of the electricity distribution. In this paper, the studied tariff structures were a power-based tariff structure based on a cost-causation principle and a power-based tariff structure with power and time limits. The customer specific relative and absolute changes in the annual electricity distribution fees were analysed and by emphasizing the customer acceptance an acceptable pathway was created.

Earthing Systems Connected via Metallic Screens of the 20 Kv Underground Cables in Non-urban Areas

Secondary substations’ earthing systems are connected to each other via metallic screens of the 20 kV underground cables also in suburban and rural areas nowadays. Topology is different from the earthing systems in city centers, where earthing is connected via multiple mesh connections forming a solid ground level. The standards EN 61936-1, EN 50522 and the Finnish SFS 6001 (High voltage installations) do not clearly consider the case of connected earthing. In 2015 studies were launched to investigate this issue. According to results of the studies, the connected earthing should be evaluated as a whole, and not separately as in the overhead networks. There is a need for renewing earthing network design principles because at the moment, the connections between the secondary substations are not systematically taken into account in the non-urban areas’ earthing design. Results show that the resulting impedance was typically 50-80% lower than the secondary substations’ individual earthing resistances. It means that there is great potential for savings in the earthing network without risking the safety. Furthermore, there is a need to develop earthing impedance measuring methods. Methods that are used for overhead network earthing measurements are not often suitable for cable network, where the earthing are connected. This paper brings out recommendations how the design and measurement principles could be developed and which possible changes in the relevant standards should be considered.
Field testing of a wideband monitoring concept at MV side of secondary substation

Smart grid concept substantially increases the need of monitoring devices in the future for efficient and flexible power delivery. Secondary substation is an ideal location for monitoring both LV and MV networks which can be used to improve the power grid resilience. This study presents the key features and practical experience gained from the deployment of novel wideband high-frequency current transformer sensors for monitoring power quality as well as partial discharges at MV side of the transformer. Additionally, a network simulation is carried out using real-time digital simulator to test the possibility of detecting an earth fault cost-effectively at MV side of secondary substation.

General information
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Authors: Siddiqui, B., Pakonen, P., Verho, P.
Publication date: 15 Jun 2017

Generation Curtailment as a Means to Increase the Wind Power Hosting Capacity of a Real Regional Distribution Network

This paper represents how generation curtailment can be utilized to increase the wind power hosting capacity of an existing distribution network. The paper proposes a control algorithm that implements the curtailment and can be easily implemented as a part of the existing network management tools of the distribution system operator. The paper also presents how the amount of annual curtailment can be evaluated prior to wind farm construction.

General information
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Ministry of Education publication type: A4 Article in a conference publication
Organisations: Electrical Energy Engineering
Authors: Kulmala, A., Repo, S., Pylvänäinen, J.
Publication date: 15 Jun 2017
Reforming Distribution Tariffs of Small Customers: Targets, Challenges and Impacts of Implementing Novel Tariff Structures

The paper discusses the targets, challenges and impacts of novel distribution tariff structures, especially power based distribution tariffs. The paper summarizes the aims and preliminary results of an ongoing Finnish national research project in which distribution tariffs are being investigated together with multiple distribution system operators (DSO), research institutes and other actors of the field. The reformation of distribution tariffs has some clear motivational factors, but at the same time, the topic is very multifaceted, as changes in the pricing of electricity distribution have different effects on different actors of the field like customers, DSOs, electricity retailers and other third parties in the electricity sector (e.g. different kinds of service providers, device manufacturers) and society as a whole. These topics are discussed in a qualitative manner in the paper but also preliminary numerical results are presented to elaborate the customer impacts of novel tariffs.

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.
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 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.

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Organisations: Electrical Energy Engineering, Research area: Power engineering
Authors: Lappalainen, K., Valkealahti, S.
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Peer-reviewed: Yes

Publication information
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Volume: 144
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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Scopus rating (2015): SJR 0.384 SNIP 0.387 CiteScore 0.59
Scopus rating (2014): SJR 0.469 SNIP 0.503 CiteScore 0.68
Scopus rating (2013): SJR 0.373 SNIP 0.711 CiteScore 0.93
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 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.
Edellytykset kysyntäjouston toteutumiselle kiinteistössä

General information
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Authors: Harsia, P., Penttinen, S., Järventausta, P., Sorri, J., Aalto, P., Kallioharju, K., Kaivo-oja, J., Kojo, M., Korpela, T., Ruostetsaari, I., Oksa, A. M.
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Links:
Research output: Professional → Discussion paper

Energiatehokkuus on entistä enemmän sähkötehon hallintaa

General information
State: Published
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Organisations: Civil Engineering, Research group: Life-cycle Economics, Research group: Construction Processes
Authors: Heljo, J., Sorri, J., Harsia, P.
Number of pages: 6
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.

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.
Improving Disturbance Management with Combined Electricity and Mobile Network Situation Awareness System

General information
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Organisations: Department of Electrical Engineering, Research area: Power engineering, Department of Electronics and Communications Engineering, Research group: Laboratory of Radio Network Planning, Wapice Ltd.
Authors: Krohns-Välimäki, H., Säe, J., Haapanen, J., Verho, P., Lempiäinen, J.
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Scopus rating (2014): SJR 0.469 SNIP 0.503 CiteScore 0.68
Scopus rating (2013): SJR 0.373 SNIP 0.711 CiteScore 0.93
Scopus rating (2012): SJR 0.32 SNIP 0.529 CiteScore 1.49
Scopus rating (2011): SJR 0.306 SNIP 0.975 CiteScore 2.07
Scopus rating (2010): SJR 0.261 SNIP 0.269
Scopus rating (2009): SJR 0.15 SNIP 0.252
Original language: English
DOIs: 10.15866/iree.v11i5.10175
Pohjoismaiden energiapolitiikka 2030: Hiilineutraalimpaan energiajärjestelmään osin yhdessä, osin eri polkuja pitkin

General information
State: Published
Ministry of Education publication type: D4 Published development or research report or study
Organisations: Department of Civil Engineering, Department of Electrical Engineering, Department of Chemistry and Bioengineering, Department of Physics, Research group: Construction Processes, University of Tampere, VTT
Number of pages: 23
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Publication information

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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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Ministry of Education publication type: D4 Published development or research report or study
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Research output: Professional > Discussion paper

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 571Whkg⁻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.
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 capabilities.
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.

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 modelled 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 is needed.
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 it 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.

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Organisations: Department of Electrical Engineering, Research area: Power engineering
Authors: Rautiainen, A.
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Research output: Collection of articles › Doctoral Thesis

A Versatile Solution for Continuous On-line PD Monitoring

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Authors: Siddiqui, B., Pakonen, P., Verho, P.
Number of pages: 6
Publication date: Nov 2015

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ISSN (Electronic): 2378-8542
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10.1109/ISGT-Asia.2015.7387157
Research output: Scientific - peer-review › Conference contribution

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

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.

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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 (Uocv = 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.

General information
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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.

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.
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 be control by staff. Monte-Carlo Simulation (MCS) has used to model the fault frequencies and outage time of customers. The two tools which in 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.

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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.

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

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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.

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.
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.

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.

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.

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.

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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.

General information
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.
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.
Matlab/Simulink modeling to study the effect of partially shaded condition on photovoltaic array's maximum power point

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.
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.

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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.
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.

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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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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Authors: Krohns-Välimäki, H.
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Dynamic characteristics of three-phase Z-source-based photovoltaic inverter with asymmetric impedance network

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Effect of active damping on the output impedance of PV inverter

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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 hillitseminen on taustalla myös uusissa rakentamiseen liittyvissä energiatehokkuusmääräyksissä, joiden tavoitteena on ohjata rakentamista yhä energiatehokkaampaan ja uusiutuviin energialähteisiin hyödyntävään suuntaan. Energiatehokkuutta arvioitessa tulee kiinnittää erityistä huomiota myös taloudellisiin tehohuippuihin ja käyttöprofiileihin. Kysynnän jouston tarve ja tavoitteet tulee nähdä myös tarpeellisena osana tulevassa lähes nollaenergian eli nZEB-rakentamisessa.

Kysynnän jousto sisältää laajan joukon erilaisia toimintoja, joiden merkitys, tarve ja ansaintalogiikka vaihtelevat toimijan näkökulmasta. Kysynnän joustollan voidaan ymmärtää välillä esimerkiksi hintoja tai hintojen muutosten ongelmia. Valikoimat ja tekniset ratkaisut, joilla on tarkoitus hallinna muutosten vaikutuksen minimiin ja ennakoida mahdollisia joustamahdollisuuksia sähköverkon käyttössä.

Tekestyntäohjauksen on mahdollista erilaisissa liiketoimistossa, esimerkiksi sähköverkon ja laitevalintojen suunnittelussa, jossa ohjauksen kehittäminen on periaatteessa mahdollista, mutta teknistä suorittamista tarvitaan lisäksi. Ensiäiset ohjaukset ovat saatavilla kiertävissä ohjauksen kehittämisessä, mutta ne edellyttävät teknologian kehitystä ja resurssien tukeutumista. Ohjaukseen tarvitaan myös tietotekniikkaa, jotta ohjaukseen voidaan hakeutua tehokkaasti ja tehokkaasti.

Tutkimusprojektin lopputuloksena esitetään lukuisa joukko toimenpiteitä, joilla voidaan edesauttaa laajamittaisen kysynnän jouston yleistymistä. Vastuu toimenpiteistä jakautuu laajasti toimialan yrityksille (mm. sähkön myyjät ja verkkoyhtiöt), toimialan järjestöjen edustajille sekä viranomaisille. Toimenpiteet liittyvät:

- kysynnän jouston tuotteistamiseen sähkön myyjän ja jakeluverkkoyhtiön toimintojen osalta,
- eri sidosryhmien informointiin ja koulutukseen,
- toimintatapojen yhtenäistämiseen toimintaprosessien sekä teknisten järjestelmien osalta,
- lainsäädännön, viranomaismääräysten ja ohjeiden kehittämiseen, joihin sisältyy erityisesti verkkoliiketoiminnan valvontamallin ja rakennusmääräysten kehittäminen.

Vaikka kysynnän jouston laajamittainen käyttöönotto edellyttää vielä paljon erilaisia toimenpiteitä, niin olemassa oleva infrastrukturi ja markkinapaikat sekä meneillään oleva kehitystöö luo uskoa kysynnän joston 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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Scopus rating (2014): SJR 3.105 SNIP 3.799 CiteScore 7.77
Scopus rating (2013): SJR 3.175 SNIP 4.831 CiteScore 9.88
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.