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POWER CONTROL GRID CONNECTED SYSTEM UNDER UNBALANCED VOLTAGE CONDITIONS

[1]B MADHAVI, [2]CH NAVEEN KUMAR, [3]D NAVEENA, [4]N NIKITHA,[5]Mr. D SUBRAMANYAM

[1234]IV Year student, [5]Assistant Professor

Department of Electrical and Electronics Engineering

Visvesvaraya College of Engineering, Hyderabad.

ABSTRACT

This project to proposed by overview of the most important issues raised by the use of power systems. with respect to need for modified of existing grids in the direction of intelligent Micro grids. The main problems and bound up of the construction of Grids and the power station, as well as functioning in them of the most important power electronic systems are power quality control, both primary converters control and secondary system coordination are required. with a focus on the hybrid AC/DC micro grid harmonics compensation and unbalance compensation. For multiple interfacing converters, the secondary control with system-level coordination. Special attention is directed therein to the potential possibilities of so-called 'smart' transformers and V2G technologies.

INTRODUCTION

Smart grids are emerging as next-generation of power systems, which contain interconnected clusters of microgrids. These microgrids encompass AC and DC subgrids, called hybrid microgrids. Such hybrid microgrids are power electronic-based autonomous systems in which most generations are distributed and usually from renewable resources . As more power electronic converters from distributed generations, energy storage systems, loads etc. are used, new opportunities for power system control are emerging. Based on the Electric Power Research Institute (EPRI) and the Smart Electric Power Alliance (SEPA) reports, the smart power converters are introduced as a leastcost tool for supporting the grid and mitigating grid challenges. The recent revisions of standards and grid codes as well as communication protocols also encourage the use of smart power converters' functions. However, it should be considered that most of the converters are not utility owned and operated resources. Thus, appropriate policies and markets are required to encourage more ancillary functions. For example, Arizona Public Service (APS) is working on the installation of smart power converters for about 1,500 home solar systems (about 10 megawatts in total). They devote $30 per month bill credit for participants for 20 years for turning over their inverters to real-time controls and utility data collection that can be used for ancillary services. In hybrid microgrids, increasing single-phase/unbalanced loads, non-linear loads, and single-phase/unbalance distributed generations leads to power quality challenges. For example, more efficient loads such as Compact Fluorescent Lamp (CFL), LED, adjustable speed drives (ASD) fridge, etc.

LITERATURE REVIEW

The Effects on Energy Markets of Achieving a 1.5 °C Scenario

Net zero emission scenarios are aligned with the criteria for the Paris Agreement to keep global warming below 1.5 °C. By soft-linking an energy model with a macroeconomic model, we create a similar pathway to the net zero emission scenario from the International Energy Agency (IEA) to 2050 both of demand for fossil fuels and total CO_2 emissions. Soft-linking entails that we insert endogenous variables from one model into the other model. We implement measures such as CO_2 taxes, improved energy efficiency, more renewables in electricity production and other sectors, easier substitution between electricity and fossil fuels for final users, and drastically limiting future production of oil, gas and coal. Our conclusion is that net zero is possible by introducing very strict measures, e.g., a high rate of energy efficiency improvement, far above what has been achieved in the past. While our partial equilibrium energy model, similar to the IEA model, overlooks the potential rebound effects, i.e., more energy used by consumers due to lower prices caused by energy efficiency improvement, our macroeconomic model does capture the rebound effects and has to implement stricter supply-side measures to reduce fossil fuel use to achieve the 1.5 °C scenario.

To keep global temperature increase below 1.5 or 2 °C compared to pre-industrial levels, the global CO_2 emissions will need to become net zero and potentially below zero. As indicated by the Intergovernmental Panel on Climate Change (IPCC) in its special report on 1.5 °C: "From a physical science perspective, limiting human-induced global warming to a specific level requires limiting cumulative CO_2 emissions, reaching at least net zero CO_2 emissions, along with strong reductions in other greenhouse gas emissions" [1]. Jones et al. [2] suggest that, essentially, the global warming stops in the case of net zero CO_2 emissions, implying that current choices can avoid the worst impacts of global warming in the future. Net zero energy systems, where residual CO_2 emissions are offset by removals, are crucial to achieve economy-wide net zero emissions (see e.g., [3]).

The Paris Agreement from 2016 proposes an ambitious target of limiting global warming to well below 2 °C, preferably to 1.5 °C, compared to pre-industrial levels. This was strengthened to below 1.5 °C at the Glasgow meeting in 2021. There is a strand of studies using integrated models that analyze how 1.5 °C can be reached, e.g., the IPCC-scenarios presented in Masson-Delmotte et al. [1]. In 2021, a report released by the IEA [4] described a roadmap to achieve net zero emissions for the global energy sector by 2050 (NZE hereafter), which is necessary for a 1.5 °C world.

The purpose of this study is to examine how global energy markets might be affected during the transition period of achieving net zero emissions in 2050 based on two soft-linked complementary models. Soft-linking entails that we insert endogenous variables from one model into the other model. The IEA [4] presents the most-cited and well-known NZE pathway for energy sectors (we refer to this scenario as NZE IEA). Brecha et al. [5] have assessed various scenarios, including those from the IPCC reports, and find that the NZE IEA scenario is aligned best with the requirement specified in the Paris Agreement when it comes to having the likelihood to limit global warming to 1.5 °C. To the best of our knowledge, we have not seen any studies that use energy models to test whether the NZE IEA pathway is achievable and which relevant measures to apply to reach such a pathway. By soft-linking an energy model with a macroeconomic model, this study creates a similar pathway to 2050 and analyzes how such a pathway impacts the energy markets.

We introduce various mitigation measures simultaneously to achieve NZE in 2050 in our models. Among them, we consider CO_2 taxes, improved energy efficiency, more renewables in electricity production and other sectors, easier substitution between electricity and fossil fuels for final users, and drastically limiting future production of fossil fuels. The effect of our various measures is to reduce fossil fuel consumption and corresponding emissions to around 90 per cent from the reference scenario by 2050. Even if it is possible to reach large reductions by implementing such strict measures, it would in practice be very challenging, if not impossible. By presenting the NZE scenarios simulated by our models, the paper aims to discuss the magnitude of the various measures that are necessary to obtain NZE and whether this is realistic or not.

Electricity Generation in LCA of Electric Vehicles: A Review

Life Cycle assessments (LCAs) on electric mobility are providing a plethora of diverging results. 44 articles, published from 2008 to 2018 have been investigated in this review, in order to find the extent and the reason behind this deviation. The first hurdle can be found in the goal definition, followed by the modelling choice, as both are generally incomplete and inconsistent. These gaps influence the choices made in the Life Cycle Inventory (LCI) stage, particularly in regards to the selection of the electricity mix. A statistical regression is made with results available in the literature. It emerges that, despite the wide-ranging scopes and the numerous variables present in the assessments, the electricity mix's carbon intensity can explain 70% of the variability of the results. This encourages a shared framework to drive practitioners in the execution of the assessment and policy makers in the interpretation of the results.

Electric mobility is gaining momentum as a promising technology for decarbonisation of the transport sector and lots of scientific papers assessing environmental impacts of electric vehicles (EVs) are being produced. However, as the literature grows, so do the number of conflicting results.

A few reviews have tried to find a pattern in the Life Cycle Assessment (LCA) results: Hawkins et al. [1] identify the lack of a transparent and complete Life Cycle Inventory (LCI) as one of the main gaps in LCA. On the other hand, a more recent review by Nordelöf et al. [2] argues that the absence of a complete goal definition is the main hurdle to correctly interpret results and find trends in the literature.

Since the goal dictates the line for the subsequent scope and defines the applications of the study, omitting this phase leaves the study as a missive without address in the scientific community, and thus potentially ineffective.

Hawkins et al. focused on the necessity to find consensus on the inventory. At the time of Hawkins' publication, it was found that most studies limited their attention to a well-to-wheel analysis—since the use phase was seen to dominate the life cycle of vehicles, or to the battery production. The author's purpose was then to investigate all those aspects that were not sufficiently addressed, providing the practitioner with a standardised system boundary and a set of relevant sub-components that could be distinguishable in the production phase.

The main causes of divergence in the literature, which make it difficult to compare studies are identified as follows by Hawkins et al. [1]: Different system boundaries, different level of detail and quality in the datasets, different lifetimes, different vehicles' typologies and masses, battery technologies, vehicles performances, and then the electricity mix.

Nordelöf et al. [2] present an exhaustive analysis, and performs various meta-analyses from the findings of LCAs. They also widen the discussion to impact categories like resource depletion and toxicity, while the Hawkins's focus remained on climate change.

Both reviews identified electricity production as the most impactful phase when it comes to climate change, and agreed on the need to find consensus on the appropriate electricity mix.

Since these two seminal reviews have been published, a variety of papers appeared in the literature, paving the way to new and interesting discussions as well as diverging results and methods.

A significant change in the way to account for electricity in the use phase of electric vehicles has occurred in the last few years: from an overgeneralisation of the inventory, using generic datasets (from EcoInvent, Emissions & Generation Resource Integrated Database [eGRID], Greenhouse gases Regulated Emissions and Energy use in Transportation [GREET], etc.…), the trend in the most recent LCAs has been a high detail of temporal and spatial variability, following the work by Graff Zivin et al. [3].

A blossoming of different methods to account for the "correct" electricity mix has led to lots of different, and sometime conflicting, results.

Lack of consensus in LCI data selection and lack of clear goal definitions are still the key factors to explain the difficult path of providing policy makers with robust and clear results.

A Review on Internet of Things for Defense and Public Safety

The Internet of Things (IoT) is undeniably transforming the way that organizations communicate and organize everyday businesses and industrial procedures. Its adoption has proven well suited for sectors that manage a large number of assets and coordinate complex and distributed processes. This survey analyzes the great potential for applying IoT technologies (i.e., data-driven applications or embedded automation and intelligent adaptive systems) to revolutionize modern warfare and provide benefits similar to those in industry. It identifies scenarios where Defense and Public Safety (PS) could leverage better commercial IoT capabilities to deliver greater survivability to the warfighter or first responders, while reducing costs and increasing operation efficiency and effectiveness. This article reviews the main tactical requirements and the architecture, examining gaps and shortcomings in existing IoT systems across the military field and mission-critical scenarios. The review characterizes the open challenges for a broad deployment and presents a research roadmap for enabling an affordable IoT for defense and PS.

The Internet of Things (IoT) is a distributed system for creating value out of data. It enables heterogeneous physical objects to share information and coordinate decisions. The impact of IoT in the commercial sector results in significant improvements in efficiency, productivity, profitability, decision-making and effectiveness. IoT is transforming how products and services are developed and distributed, and how infrastructures are managed and maintained. It is also redefining the interaction between people and machines. From energy monitoring on a factory [1] to tracking supply chains [2], IoT optimizes the performance of the equipment and enhances the safety of workers. Until today, it has allowed for more effective monitoring and coordination of manufacturing, supply chains, transportation systems, healthcare, infrastructure, security, operations, and industrial automation, among other sectors and processes.

Currently, the industrial and business sector is leading the adoption of IoT. Businesses will spend $3 billion in the IoT ecosystem and deploy 11.2 billion devices by 2020, while customers will invest up to $900 million [5]. On the other hand, the public sector is estimated to increase significantly its adoption and spend up to $2.1 billion and install 7.7 billion devices, being the second-largest adopter of IoT ecosystems, particularly in areas like smart cities [6,7], energy management [8] and transportation [9].

IoT represents the convergence of several interdisciplinary domains [10,11,12,13,14]: networking, embedded hardware, radio spectrum, mobile computing, communication technologies, software architectures, sensing technologies, energy efficiency, information management, and data analytics. The rapid growth of IoT is driven by four key advances in digital technologies. The first one is the declining cost and miniaturization of ever more powerful microelectronics such as transducers (sensors and actuators), processing units (e.g., microcontrollers, microprocessors, SOCs (System-on-a-chip), FPGAs (Field-Programmable Gate Array), and receivers. The second factor is the fast pace and expansion of wireless connectivity. The third is the expansion of data storage and the processing capacity of computational systems. Finally, the fourth one is the advent of innovative software applications and analytics, including advancements in machine-learning techniques for big data processing. These four drivers are present in the layers of the IoT technology stack. For instance, IoT may include transducers that collect data on physical and environmental conditions. These devices transmit data over a wired or wireless communication network to servers and computers that store and process data using software applications and analytics. The knowledge gleaned from the analysis can be used for fault detection, control, prediction, monitoring, and optimization of processes and systems.

Combination of Synchronous Condenser and Synthetic Inertia for Frequency Stability Enhancement in Low-Inertia Systems

Inertia reduction due to high-level penetration of converter interfaced components may result in frequency stability issues. This paper proposes and analyzes different strategies using synchronous condenser (SC), synthetic inertia (SI) of wind power plant, and their combination to enhance the frequency stability of low-inertia systems under various scenarios and wind conditions. Furthermore, one of the SC models includes hardware of automatic voltage regulator (AVR) for better representation of the reality is implemented. The simplified Western Danish power system simulated in real-time digital simulator is used as a test system of low inertia to demonstrate the effectiveness of the strategies. The comparative results show that the combination of SC with AVR hardware-in-the-loop test and SI offers a better improvement not only on frequency stability (rate of change of frequency and frequency deviation) but also on the system synchronism under various operating conditions.

WITH the replacement of conventional generation by power electronic-based generation such as wind power plants, photovoltatics plants, and importing high-voltage direct current (HVDC) links, the significant inherent rotational inertia property of traditional power plants is displaced by a smaller or no rotational inertia of converter interfaced generation. Therefore, high-level power electronic-based generation penetration makes the system inertia reduce that leads to the system frequency more vulnerable and probable frequency instability under severe disturbances. Manuscript received July 18, 2017; revised February 1, 2018 and June 29, 2018; accepted July 10, 2018. Date of publication July 18, 2018; date of current version June 20, 2019.

There have been many researchers considering the impact of low inertia on power system stability and operation because of high renewable energy penetration level [1]–[3]. In [1], a research related to system inertia and the challenge in the system operation due to the inertia reduction are investigated. The study proposes using storage devices or inertia of converter connected generation as a solution for low inertia systems. Maintaining sufficient inertia in the system to guarantee operational security is a main challenge of the Nordic power system [2]. The low inertia effect on power system operation and stability with high converter-connected wind turbine and photovoltaic penetration level is analyzed in [3]. The paper demonstrates that system inertia becomes heterogeneous and frequency dynamics are faster in power systems with low inertia. Recently, 1200 MW photovoltaic resource interruption incident in the Southern California system is occurred due to low system frequency condition that activates inverters trip based on the instantaneous frequency measurement during a fault [4]. Consequently, the low inertia issue has been generally recognized. To improve the frequency stability, transmission system operators (TSOs) have issued grid codes to the participation of wind power plants (WPPs) in frequency control [5].

In addition, the role and potential ability of WPPs for supporting frequency control have been investigated in [6] that provides foreseeable ideas for further research work on WPPs. Recent literature proposed strategies on implementing inertial support of WPPs, the so-called synthetic inertia (SI), most of them propose a supplementary control into active power loop that is activated during frequency changes. It can be classified into two main categories. The first one attempts to mimic the inertial response of conventional power plants [7], [8] that uses df /dt as an input signal, while the second one takes frequency deviation as an input signal with fast response time [9], [10]. The authors in [11] use the combination of the two control strategies to provide inertial response for WPP. An ancillary control signal proportional to df /dt and frequency deviation is used to increase/decrease the electric power of WPP. A number of authors have paid more attention to the activation schemes instead of control methods for SI implementation [12], [13]. A coordination of inertial response and grid event detector using a demanded inertia methods are proposed and analyzed in [13] that focuses on trigger schemes without coordinated with the control. Based on the above-mentioned literature, a fulfilled control strategy investigated both the control method and the activation scheme for SI of WPPs has not done yet. Moreover, the synthetic inertia from WPPs is not fast enough to react in severe disturbances. Synchronous condenser (SC) has been playing an important role in reactive power compensation and keeping voltage stability in power systems for a couple of decades [14]. By varying the field excitation current, SC can operate at over-excited or under-excited modes to supply/absorb reactive power to/from the network that can control smoothly the voltage or keep the system power factor at a specified level. SC can also support the short-circuit power to the network that can improve system interconnections, facilitates system protection and enhances the operation of modern power electronics installations [15].

Furthermore, using SC for decreasing under frequency load shedding is investigated in [16] and a interaction between active power and reactive power channels of synchronous condensers to improve primary frequency control is studied in [17]. Completely different from WPPs, SC is an alternator that can provide inherently inertial response due to the electromechanical coupling with the grid. The kinetic energy stored in its rotating mass can naturally counteract the frequency change during disturbances. From the literature review, the difference between SC and SI in terms of frequency support is not very well clarified. In this paper, synchronous condenser and SI of WPPs are investigated and clearly shown for the frequency stability improvement of low inertia systems. Firstly, usage SC providing the inherent rotating energy to support inertial response that helps primary control has more time to react during system frequency changes. The SC model includes a real automatic voltage regulator (AVR) system that is interfaced with the simulation through hardwarein-the-loop (HiL). HiL provides an efficient real-time control and a safe environment where tests can focus on the functionality of the controller and verify all dynamic conditions of the system, which is hard to implement in real devices [18], [19]. During HiL test, the physical system of AVR interfaces with the rest of SC and the grid that are simulated in real-time digital simulator (RTDS), and the outputs of the simulation imitate the actual output of the physical AVR system. Secondly, a SI controller of WPPs and its activation scheme are proposed. The difference of inertia characteristic between SC and SI for the frequency control is analyzed. Finally, a combination of SC and SI is examined that shows a better performance not only in frequency stability enhancement but also in system frequency synchronism. These methods are demonstrated on the future Western Danish renewable-based (DK1) system to analyze their performance during disturbances. Different scenarios and wind speed conditions are investigated to examine the effectiveness of these approaches.

Enhancement of the Flickermeter for Grid-Connected Wind Turbines

Distributed generators connected to the power system usually produce voltage fluctuations. For wind turbines connected to a grid, large changes in wind speed can cause voltage flicker at the point of common coupling. The measurement of voltage flicker caused only by wind turbines is difficult. The wind turbine under test is usually connected to a medium voltage point, in which other fluctuating loads may produce significant voltage disturbances at the wind turbine terminal where the measurement is made. Although the IEC 61400-21-1 standard specifies a method to evaluate voltage flicker caused by wind turbines, because of the complex algorithm and process of the IEC standard, there is currently a lack of measurement equipment that meets the IEC standard. In addition, some countries that use other voltage flicker standards, such as ΔV_{10}, do not have suitable flicker measurements for wind turbines. Therefore, this study proposes an enhanced version of the IEC 61400-21-1 standard, which integrates the ΔV_{10} method, so that the proposed measurement system complies with the IEC and ΔV_{10} standards. In this study, the voltage flicker measurement system is successfully implemented, which can help engineers to predict the voltage flicker by wind turbines and assess whether a region or grid is suitable for installing wind turbines. Therefore, it can provide wind turbine companies with a quick assessment of voltage flicker to comply with the certification process.

Wind energy is a safe, clean, and endless renewable energy source. Because wind energy has no fuel and air pollution problems, in the face of the current climate abnormalities and global warming, wind energy technology has attracted more and more attention from the world [1,2]. Although wind power is a sustainable energy, when the wind power generator is merged with or disconnected from the existing electric power system, it will cause voltage fluctuations and short-circuit current in the grid, thereby affecting power quality. Furthermore, the inherently unstable wind speed can also cause the wind turbines to produce voltage fluctuations, called voltage flicker [3,4,5,6]. Voltage flicker will not only cause unstable lighting of lamps, but also cause health problems and electronic equipment failure [7]. Therefore, measuring voltage flicker becomes an important issue of power quality. The flickermeter standard IEC 61000-4-15 was developed by the International Electrotechnical Commission and has been widely used worldwide for decades [7]. It can evaluate the flicker severity level of power supply voltage as the values of P_{st} (short-term flicker severity) and P_{lt} (long-term flicker severity). However, the IEC 61000-4-15 flickermeter is not suitable for directly measuring the voltage flicker caused by wind turbines, because the tested wind turbine is usually connected to a medium voltage point, and other fluctuating loads may generate obvious voltage perturbations in the grid during measurement. Thus, the IEC announced the standard of IEC 61400-21-1 in 2019 [8] for evaluating the voltage flicker caused by grid-connected wind turbines, which is partially based on the IEC 61000-4-15 standard.

Wind turbine companies need a certification process for selling wind turbines. Gutierrez et al. [9] presented a flicker measurement system for wind turbines' certification based on the IEC standard. The system consisted of two modules: a signal register to store the voltage and current time-series data and a process algorithm in accordance with the IEC standard. The IEC standard method is based on measuring the flicker of a single wind turbine and then using this measurement result to calculate the flicker emission from a number of wind turbines. Therefore, Barahona et al. [10] investigated the validity and accuracy of the standard method in IEC 61400-21, i.e., the early version of IEC 61400-21-1, for evaluating the flicker emission from multiple wind turbines. Dexiong Li [11] revealed that the fictitious grid circuit provided in the IEC standard should not connect a current source with an inductor in series.

Thus, two new fictitious grid circuits were proposed to improve the deficiency. Khan et al. [12] worked on the deviation on flicker evaluation of wind turbines associating with the disturbance of harmonics and interharmonics. However, because of the complexity of the algorithm and process of the IEC 61400-21-1 standard, there is currently a lack of measurement equipment that meets the standard.

Another flicker measurement approach called "Equivalent 10-Hz Voltage Flicker (ΔV_{10})", developed by the Central Research Institute of the Electric Power Industry (CRIEPI) [13,14] in 1978, is widely used in Japan, Brazil, France, Italy, Argentina, and Taiwan. According to the specification of the approach, the voltage flicker severity is measured as the term of ΔV_{10} value, and the maximum value of the evaluation index ΔV_{10} should not exceed 0.45% as the basis for regulation. However, the CRIEPI does not provided a method to evaluate the voltage flicker caused by wind turbines. Although the works in Gherasim [15], Redondo [16,17], and Manas [18] implemented the flickermeter based on the IEC standard for wind turbines, the ΔV_{10} standard has not been considered. Thus, in this work, we added the ΔV_{10} method into the IEC 61400-21-1 standard to propose an enhanced version of the two-mode IEC voltage flicker measurement for wind turbines, which is suitable for countries using the IEC standard or the ΔV_{10} standard.

To implement this proposed method, MATLAB Simulink is used to build a model of a doubly fed induction generator (DFIG) with grid connection to generate current and voltage time-series data at the wind turbine terminals to simulate the voltage flicker on the virtual grid without other voltage fluctuation loads. A measurement system based on the IEC 61400-21-1 combined with ΔV_{10} standard was implemented to assess the voltage flicker caused by wind turbines under continuous operation. It can help wind turbine companies with a quick certification of power quality for wind turbine installations. The proposed system can evaluate whether a region or grid is suitable for installing wind turbines. It can also predict the voltage flicker that wind turbines may cause in advance.

An Overview of Transmission Line Protection by Artificial Neural Network: Fault Detection, Fault Classification, Fault Location, and Fault Direction Discrimination

Contemporary power systems are associated with serious issues of faults on high voltage transmission lines. Instant isolation of fault is necessary to maintain the system stability. Protective relay utilizes current and voltage signals to detect, classify, and locate the fault in transmission line. A trip signal will be sent by the relay to a circuit breaker with the purpose of disconnecting the faulted line from the rest of the system in case of a disturbance for maintaining the stability of the remaining healthy system. This paper focuses on the studies of fault detection, fault classification, fault location, fault phase selection, and fault direction discrimination by using artificial neural networks approach. Artificial neural networks are valuable for power system applications as they can be trained with offline data. Efforts have been made in this study to incorporate and review approximately all important techniques and philosophies of transmission line protection reported in the literature till June 2014. This comprehensive and exhaustive survey will reduce the difficulty of new researchers to evaluate different ANN based techniques with a set of references of all concerned contributions.

There is no fault-free system and it is neither practical nor economical to build a fault-free system. The various cases of abnormal circumstances such as natural events, physical accidents, equipment failure, and misoperation generate faults in the power system. The consequences of faults are traumatic amplification of current flow, increasing heat produced in the conductors leading to the major cause of damage. The actual magnitude of fault depends on resistance to flow and varied impedance between the fault and the source of power supply. Total impedance comprises of fault resistance, resistance and reactance of line conductors, impedance of transformer, reactance of the circuit, and impedance of generating station. The conventional distance relay settings are based on a predetermined network configuration with worst fault outcomes [1–6]. As the neural network based algorithm has more adaptability and is likely to be more accurate, various researchers used it for power system protection which is the main focus of this study. A number of prime purposes and applications of ANN are accessible in the literatures; those will assist to recognize the perception of accepting it as a tool for fault detection, classification, and localization on transmission line of the power systems. Various journals, conference papers, books, online libraries, and databases were researched and reviewed for gathering proper information to develop a broad insight and comprehension of the subject being studied. Both scholarly and nonscholarly articles were surveyed and considered from databases like IEEE, Scopus, Google Scholar, Academia Search Premier, Pro-Quest, EBSCO, and other relevant websites.

The paper is organized as follows. In Sections 2 and 3, a brief introduction of power system faults and artificial neural networks is provided, Section 4 is about distance protection by ANN method; in Section 5, ANN and its application for protecting transmission line are illustrated. Section 6 deals with the conclusions drawn from this survey followed by acknowledgments and references.

Impact of VSC Control Strategies and Incorporation of Synchronous Condensers on Distance Protection Under Unbalanced Faults

The short circuit response of a voltage source converter (VSC) under grid unbalanced faults mainly depends on the design of its control system. Due to the limited semiconductor overload capability, the short circuit current contributed by a VSC should be restricted within the limit for each phase. This might bring up challenges to the protection system of a converter-dominated power system. This paper derives a generic converter peak current limitation method for three different VSC control strategies. The impact of the control strategies and the combined impact of a VSC with a synchronous condenser on distance protection are evaluated using a commercial relay through hardware-in-the-loop (HIL) tests. Based on the test results, we propose to avoid using constant reactive power control strategy. It poses an adverse impact on the reliability and speed of distance protection regardless of the presence of a synchronous condenser at the point of common coupling, while constant active power and balanced current control strategies favor the performances of distance protection.

AS a concern of the worldwide climate change and growing demands for electricity, the integration of renewable energy into power systems has gained increasing attention. For example, Denmark aims to achieve 100% renewable energy supply by 2050, eliminating the dependency on fossil fuels [1]. This has led voltage source converter (VSC) based sources (e.g., Type-IV wind power plants, photovoltaic power plants, and HVdc transmissions) up to several hundred megawatts to be connected to the high-voltage transmission network.

However, the control system of a VSC is sensitive to grid disturbances such as unbalanced faults. The negative-sequence voltage appearing at the point of common coupling (PCC) will propagate in the VSC system affecting its control variables and hence its output [2]. If the control system is not designed properly, undesirable performances such as output voltage and current distortions, dc-link voltage oscillations and output power oscillations can be observed. This may even result in an undesirable trip of the converter. As transmission system operators have imposed strict requirements on converter-based sources such as fault-ride-through (FRT) and voltage support capability, a variety of control strategies based on symmetrical components have been proposed to improve VSC performances under unbalanced conditions. In [3]–[7], the control strategies are developed based on the objectives of achieving balanced current injection, minimization of dc voltage ripples or nullifying oscillations in either active or reactive powers. Generally, the above-mentioned control strategies can be regarded as different special cases of [8], where flexible scalars are introduced to form the current references to flexibly control the oscillations in the active and reactive powers. In [9], the relative relationship between the positiveand negative-sequence powers can be flexibly adjusted. Based on [9], the studies in [10]–[12] regulate the grid phase voltages complying to predefined boundaries and the study in [13] focuses on the effectiveness of unbalanced voltage compensation. With converter current restricted in each phase, Camacho et al. [14] and Sosa et al. [15] aim to maximally use the power capability of the converter under unbalanced faults. Therefore, the short circuit response of a VSC can be significantly different from each other under unbalanced faults, and which control strategy is more suitable is still under open discussion. Distance protection is widely utilized in high-voltage transmission networks and a variety of studies has been conducted regarding the impact of VSCs on distance protection. The speed of distance relays subject to balanced faults is evaluated by simulations in [16], where different fault types and penetration levels of renewable generation are examined. In [17], distance relays may refuse to trip when there is not enough fault current under balanced faults and communication-aided protection is suggested to overcome this problem. According to [18], the control action of VSCs may cause an underreaching problem for the backup distance protection located on adjacent lines. However, the studies mentioned above neither discuss.

unbalanced faults nor test on a real distance relay. Even though unbalanced faults are of interests in [19]–[24], none of them has considered the impact of different VSC control strategies incorporating a converter current limit in each phase. With conventional power plants gradually replaced by converter-based generations, a future power system may experience significant drops on the system short circuit strength.

This could raise problems, such as voltage instability, undesirable dynamic behaviors of converters, and malfunctions of protection systems. Since the short circuit response of a synchronous condenser (SC) resembles that of a synchronous generator (SG), SCs may serve as an alternative to improve the system short circuit strength and thus the application of SCs has gained increasing attention in recent years [25]–[29]. The refurbishment of conventional power plants to SCs have been proposed in [27] and [28] to address dynamic voltage control issues and improve system short circuit ratios. However, conventional power plants may not always serve as the best locations for SCs and newly installed SCs can be anticipated. The studies in [28] and [29] have presented methods on the optimal allocation of SCs minimizing the total cost. The results have suggested that there is a need of installing new SCs for more VSCs. Therefore, it is necessary to examine the cooperation of a VSC and an SC from protection perspective considering different VSC control strategies, which has not been investigated in the previous studies.

This paper investigates the impact of different VSC control strategies and the impact of incorporating SCs on distance protection under unbalanced faults through hardware-in-the-loop (HIL) tests. Three representative control strategies from the literature, namely constant active power, balanced current, and constant reactive power control, are examined systematically. In order to limit the converter current in each phase, a generic converter peak current limitation method is derived for the examined control strategies. The tests are designed based on the variations of the sources of short circuit current, VSC control strategies, SC capacities, fault locations and types. According to the tests results from the commercial relay, we propose to avoid using constant reactive power control strategy, while constant active power and balanced current control strategies favor the performances of distance protection.

Distance Protection Analysis Applied for Distribution System with Distributed Generation

In power systems, the over-current protection scheme and, optionally with directional function, and distance function are the main protection used, principally, where the power flow is on both sides as in distribution system with distributed generation (DG), for example. However, with the increasing of DG penetration in the distribution system, these protections can not be secure and impacts in the coordination of the protection are caused due to the power flow is on both sides. Therefore, new types of protection as distance protection are candidates to solve the coordination problem in the distribution system with DG. In this paper, is proposed an application of the distance protection in the distribution system with DG, and several cases of faults and the impacts on the distance protection are evaluated in presence of DG. In the simulation and analysis of faults were varied the fault inception angle, fault type, fault resistance, and fault location. The correct and bad trips are analyzed to evaluate the distance relay performance. The distance relay used in the distribution system with DG had good performance in all simulation cases. Besides, the better performance of the distance protection proves which may be used in distribution systems with DG.

Traditionally, the distribution systems are designed to bring the electricity from substations to loads, in a one direction power flow. For this reason, the protection system was designed with the assumption that the distribution system is single source and radial [1]. Fuses and instantaneous overcurrent relays are used for radial systems with one direction flow [2]. These devices are coordinated in a way that ensures correct identification and isolation of the faulted section. [3].

With the increase of the electricity consumption, more power plants and transmission lines are needed. However, the restriction to construct new power plants and transmission lines is high, since these projects have high costs and they have the society opposition. These issues are mitigated with the usage of distributed generation (DG). The DG, which are small generating units installed next to the centers of consumption, has gained strength due to the deregulation of the energy market, distribution system operation benefits, and due to environmental issues [4–6]. New technologies applied to DG increase the diversity of energy sources, reducing dependence on fossil fuels [7].

With the penetration of DG in the distribution system, a new paradigm of protection arises, specially in protection coordination [8–11] due to the power flow being on both sides, turning the distribution system in a meshed power system. The protection used in meshed power systems (transmission lines) is usually the distance and differential protection [12]. Distance protection is the main protection in transmission lines due to several factors such as easy coordination, directionality, and only depends on line impedance [13]. This type of protection is present in several manufacturers relays used in the protection of transmission lines [14–16] and it is a consolidated technology [17].

Despite distance protection being a mature technology used in transmission line protection, several new applications are proposed in literature, such as usage in HVDC lines [18, 19], protection of lines with the presence of flexible AC transmission system (FACTS) with controllers [20], protection of UHV lines [21], protection of high voltage lines in the presence of wind power generator [22].
Regarding distance protection applications in distributed system with DG, in [23], distance protection is applied in an 11 kV power system with minor adaptions, where distance protection proves to be faster and less sensitive to source impedance than the traditional protection, even in the presence of DG. In [24], the distance protection is applied in a distributed system with DG, where distance protection does not have any major problems in the presence of DG. In addition, the advantages of distance protection over the already implanted schemes are shown. The aforementioned papers prove distance protection can be used in distribution systems with DG. However, more studies are needed, because the transient regime of the faults is not taken into account, neither the relay trip speed. These issues affect the distance protection performance and they can prevent their usage.

Modeling Of Single-Phase To Three-Phase Drive System Using Two Parallel Single-Phase Rectifiers

This paper proposes a single-phase to three-phase drive system composed of two parallel single-phase rectifiers, a three-phase inverter, and an induction motor. The proposed topology permits to reduce the rectifier switch currents, the harmonic distortion at the input converter side, and presents improvements on the fault tolerance characteristics. Even with the increase in the number of switches, the total energy loss of the proposed system may be lower than that of a conventional one. The model of the system is derived, and it is shown that the reduction of circulating current is an important objective in the system design. A suitable control strategy, including the pulse width modulation technique(PWM), is developed. Experimental results are presented as well.
Several solutions have been proposed when the objective is to supply a three-phase motor from single-phase ac mains [1]-[4]. It is quite common to have only a single phase power grid in residential, commercial, manufacturing, and mainly in rural areas, while the adjustable speed drives may request a three-phase power grid. Single-phase to three-phase ac–dc–ac conversion usually employs a full-bridge topology, which implies in ten power switches. This converter is denoted here as conventional topology. Parallel converters have been used to improve the power capability, reliability, efficiency, and redundancy. Parallel converter techniques can be employed to improve the performance of active power filters [5]-[6], uninterruptible power supplies (UPS) [7], fault tolerance of doubly fed induction generators, and three-phase drives [8]. Usually the operation of converters in parallel requires a transformer for isolation. However, weight, size, and cost associated with the transformer may make such a solution undesirable [9]. When an isolation transformer is not used, the reduction of circulating currents among different converter stages is an important objective in the system design [10]-[12]. In this paper, a single-phase to three-phase drive system composed of two parallel single-phase rectifiers and a three-phase inverter is proposed. The proposed system is conceived to operate where the single-phase utility grid is the unique option available. Compared to the conventional topology, the proposed system permits: to reduce the rectifier switch currents; the total harmonic distortion (THD) of the grid current with same switching frequency or the switching frequency with same THD of the grid current; and to increase the fault tolerance characteristics. In addition, the losses of the proposed system may be lower than that of the

conventional counterpart. The aforementioned benefits justify the initial investment of the proposed system, due to the increase of number of switches.

Evaluation of Current Controllers for Distributed Power Generation Systems

—This paper discusses the evaluation of different current controllers employed for grid-connected distributed power generation systems having variable input power, such as wind turbines and photovoltaic systems. The focus is mainly set on linear controllers such as proportional–integral, proportional–resonant, and deadbeat (DB) controllers. Additionally, an improved DB controller robust against grid impedance variation is also presented. Since the paper discusses the implementation of these controllers for grid-connected applications, their evaluation is made in three operating conditions. First, in steady-state conditions, the contribution of controllers to the total harmonic distortion of the grid current is pursued. Further on, the behavior of controllers in the case of transient conditions like input power variations and grid voltage faults is also examined. Experimental results in each case are presented in order to evaluate the performance of the controllers.

TODAY, distributed power generation systems (DPGSs) based on renewable energies are no longer regarded as one of the engineering challenges but as a potential player that can have a major contribution to the total energy production worldwide. In the last decade, exponential growth of both wind turbines (WTs) and photovoltaic (PV) power generation systems is registered [1], [2]. However, due to the stochastic behavior of the input power for both WT and PV systems, their controllability is an important issue to be considered when these systems are connected to the utility network [3]. Due to the large penetration of renewable systems in some of the European countries, more stringent interconnection demands are requested by the power system operators. The power quality and robustness to the grid voltage and frequency variations are two of the main points demanded in the latest issues of grid codes for WTs in Germany, Denmark, and

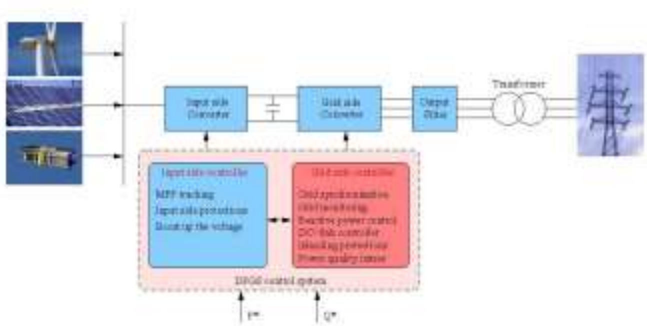

Fig. 1. General structure of a renewable energy DPGS and its main control features.

Spain [4], [5]. Consequently, there is a large interest in studying the control capabilities of distributed systems in situations of grid fault conditions. This paper discusses the control issues of the DPGS in order to fulfill the grid demands regarding power quality and grid faults ride-through. Since the demands are more stringent in the WT case, focus is set on these systems rather than PV systems. First, a general structure of a DPGS is described, highlighting some possible control tasks. Second, the grid converter control is analyzed in detail, and possible control loops and considerations in case of grid faults are given. Further on, the considered controllers are investigated and evaluated in terms of power quality, input power variations, and low-voltage grid ride-through. Finally, experimental results are presented to validate the evaluation of the controllers discussed in this paper.

GRID INTERCONNECTION OF RENEWABLE ENERGY SOURCES AT DISTRIBUTION LEVEL WITH POWER QUALITY IMPROVEMENT FEATURES

Fossil fuel resources are our main source of energyand they are depleting. Fossil fuels are non renewable and environmentally damaging. As huge increase in global warming and air pollution, fossil fuels are diminishing and their continuous increase inmoney value have made it necessary to take step towards renewable sources in coming future. There are numerous renewable energy sources (RES) such as solar, wind, tidal and biomass etc. Wind energy has great potential to supply energy with minimum impact on the environment, since it is clean and pollution free. Many researchers are finding solutions to overcome a global energy crisis, the recent developments in systems of wind energy have attracted many researchers in recent years. The government is providing subsidiaries to further increase the use of grid-connected wind and solar systems.

With increase in wind and solar generation, Renewable Energy Sources have witnessed tremendous growth in integrated power system grid connected networkat distribution level due to increase in load demand which utilize power electronic converters. Because of largeusesof power electronic devicesbasically non linear load causes disturbances in supply network. All non linear loads induces harmonics in power system grid,which causes a equipment overheating, EMI, Damage to voltage sensitive devices etc. Fewof the researchers considerharmonics is biggest problem in the power system, and some of the researchers considerit as a opportunity for development of harmonic filter. Harmonics in power distribution system are voltage or current, which are integer multiples of fundamental frequency, e.g. 50 Hz, then 3rdharmonic is 150Hz, 5th is 250Hz. Typically, voltage and current waveforms are considered to be perfect sinusoidal. Moreover, because of the increased uses of power electronicdevicesand non linear loads, thecurrent waveforms have become distorted. Thedeviation from a perfect sine wave is a result of content of the harmonic components having a frequency that is an integer multiple of the fundamental frequency. Several methods are described in various papers to solve these problems. There are standards that determine the maximumallowable level for each harmonic in the Alternative Current (AC).

CONCLUSION

For power transfer in Microgrids from AC to DC and vice versa, a Linear Quadratic Regulator (LQR) controller is proposed (for the interlink convertor) to insure stability, obtain fast response and eliminate overshooting. The performance of the LQR is compared with the open loop system and the PI controller. The step response of the convertor current with the LQR shows a lot of improvement as the overshoot, steady state error and settling time were reduced. The system transient response became very smooth and robust with the power transferred from the AC to the DC grid and vice versa.

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