

Micro grid operation and protection engineering essay

[Engineering](#)



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LITERATURE REVIEW ON

MICRO-GRID**OPERATION AND PROTECTION****Supervisor 1: Dr. Jayashri Ravishankar A/Prof John Fletcher****Supervisor 2: A/Prof John Fletcher Dr. Jayashri Ravishankar**

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Electricity demand has been continuously significantly increased over 55 times from 102TWh in 1990 to 142TWh in 2008 [1]. With the traditional technologies, fossil fuel like coal and nature gas are burnt to convert to electricity energy in large scale power plants. Hydro power plays an important role in many countries, such as Norway or Sweden while nuclear power is crucial in Japan or France. However this is not the case of Australia with the majority of electricity manufactured by coal-fired power plants. There is no doubt that the more fossil fuel is burnt, the more polluted environment will be. Global warming, floods, skin cancers seem to be the negative effects of damage of environment. This situation needs an urgent solution for the near future. While arrays of research have been carried out

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with the aim of improving traditional conversion efficiency from primary energy to electricity, advance technologies for network are carefully considered, such as DC transmission and distribution networks, mega networks, smart grids or microgrids. Among these promising solutions, concept of microgrids has been paid attention by researchers more frequent in recent years as it has become more important within modern power systems nowadays in terms of a possible means of achieving clean energy generation with updated generation technologies, such as: gas turbines, fuel cells, photovoltaic systems or wind turbines [2]. The main operation modes of microgrids are interconnected or islanded with the main grid. In the former mode, the distributed energy resources in the microgrids contribute the majority of the consumption demand and the difference in supply and demand is made available from the utility; while in the latter mode, distributed energy resources can independently supply reliable and economic energy serving different loads like residential buildings, commercial buildings and industrial parks [3]. With the continuous development of this new network type, the needs for improvement of network reliability, power quality and losses reduction are the required urgent actions. Moreover, being new candidate compared to traditional distribution network, there is a lack of consistent regulations and standards that can be applied internationally. The aim of this research is to develop a novel protection mechanism for advanced microgrids based on the characteristics of the current components. A careful analysis of transient state within distribution network in general and microgrid in specific will be carried out as a requirement before exploring modelling and controlling

devices. Improvement of proposed protection system intends to enhance reliability of overall grid, reduce losses at lower operation and maintenance costs. With above ultimate target, the most important background on microgrids concerns will be covered in Section 2 as preparation for further studies. A review of current works and remarkable contributions so far worldwide are then discussed in Section 3. Research methodology will be proposed and concluded in Section 4.

2

BACKGROUND & THEORY

This section will introduce definition of a microgrid that has been widely accepted by researchers and organisation globally. Essential background of conventional distribution network that can be applied to microgrids is the collated and summarized for further studies and references. Key considerations compose of standards for new network, different operation modes, protection basics and earthing configurations. Purposes of this Section

2.1 What is a microgrid?

The concept of a microgrid is not new to the industry since they are small-scale real electrical networks, which include generators, transformers, conductors and loads. The emergence of Micro-Grids in the Australian electricity network is anticipated, as a possible pathway of achieving clean energy generation outlined by MRET [1]. Mmicrogrids are low voltage (LV) networks with total installed capacity up to 10MVA. mMicrogrids are often defined as a group of Distributed Energy Sources (or resources commonly

referred to as DERs) and associated loads, that operate interconnected with the main grid. In other words a microgrid is defined as " the portion of an electric power distribution system, which is located downstream of the distribution substation and it includes a variety of DERs and different types of end users of electricity". Microgrids can be conceived to use DC or AC voltage in the local grid. Also, there are AC sources or microgrids interconnected by means of power-electronic interfaces to a DC microgrid. Thus, hybrid DC-AC microgrids are often implemented and it is necessary to control the power flow between DC and AC parts. Often inverters are used in such systems and as per the Australian Standards (AS 4777. 2), the DC output current of the inverter at the AC terminals, shall not exceed 0. 5% of its rated per-phase output current or 5 mA, whichever is greater. Also, it seems reasonable that the DC microgrid area can be connected to energy storage systems like batteries, super capacitors, or SMES. Thus, there is a notable increase of DC microgrid projects and these employ the well-established high-voltage applications for DC transmission and distribution systems. Microgrid can operate interconnected to the low voltage distribution grid, or in an islanded mode. While connected to the grid, the micro-sources in the microgrid contribute to the majority of the demand within the microgrid and the difference in supply and demand is made available from the utility.

2. 2 Typical configuration

A possible configuration of a microgrid is illustrated as [4], Figure : Main Components of microgridsAs can be seen from the diagram, a typical microgrid in grid-connected mode is fed from a LV feeder of a station. Main

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components might be micro-source driven by renewable energies in most cases and consumer loads connected to DERs via numbers of circuit breakers. Main functional devices are listed as below.

Switching Devices

Micro sources or loads are usually connected to distribution network using various types of switching devices. Among them, isolator and circuit breaker are the two common alternatives for microgrids. They play an important role in terms of reliability of the system by improving indices SAIFI, SAIDI, CAIDI, ASAI, ASUI and EUE [5]

Micro Sources

Sources or generators within microgrids are DER renewables in most of the cases. These sources range from tens to hundreds of kW supplying loads locally in islanding mode or a major proportion of demand in grid-connected mode. Photovoltaic arrays or fuel cell, small wind turbines, biogas turbines are typical kinds of micro sources in different countries. Since these turbines have low capacities and generated frequencies, voltage may vary due to the intermittencyunstable of primary energies, such as wind or solar, power electronics interfaces are required to stabilise and connectto connect them to the main grid.

Power Electronics Interfaces

As mentioned above, power interfaces are crucial parts of microgrids, which compose of inverters and/or converters. For the case of wind turbines, inverters first transform AC from grid into DC and then feed to buffers.

Buffers may contain capacitors to keep DC voltage level as stable as

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possible. Inverters are then used to invert DC current into AC current with various frequencies feeding to rotors of double-fed-induction-generators (where variable speed wind turbine is preferred). This configuration is called back-to-back inverters. The situation is quite different for the case of PV arrays, where a large enough storage may be installed to store captured energies and then an inverter is used to invert DC voltage to AC with suitable frequency in order to connect to main grid. By varying relative electrical angle between voltage and current, power electronics interfaces have capability to generate sinusoidal ac voltages and currents as well as be able to control the bidirectional power flow. In advance interfaces, converters must have galvanic isolation, which may handle grid disturbances or unsymmetrical voltages.

Loads

Loads of microgrids might be residential buildings, commercial buildings and industrial parks supplied from DERs [3]. Sub-classes of such loads are lighting systems, data and communication systems, control systems, safety systems, and equipment for heat, ventilation, and air conditioning [6].

Electronic loads, such as computers and lighting appliances may be directly supplied using DC without any modifications [7]. Less important AC loads, which can suffer short interruptions can be connected to the AC microgrids.

2. 3 Standard for microgrids

IEEE 1574

Institute of Electrical and Electronics Engineers (IEEE) Standard 1547. 4 is part of the IEEE 1547™ series of standards. This important standard for

microgrids was approved since 26 June 2011 [8]. Although IEEE claims that this standard cannot be used instead of laws or regulations, it contributes significant technical guidelines for microgrids. Its main contents cover intentional islands in electric power systems (EPSs), which consist of distributed energy resources (DRs). As stated in this standard, intentionally islanded DRs distributed energy resources are often referred to as microgrids in terms of local or area EPS islands. IEEE 1547.4 Standard was specifically developed to address the lack of information included in IEEE 1547-2003 Standard regarding intentional islands. With the title "Guide for Design, Operation, and Integration of Distributed Resources Island Systems with Electric Power Systems", this standard addresses crucial aspects of microgrids from design stages to operation stages, such as an overview of the general considerations for design and operation of DR island systems and describes the various types of DR island systems. Considerations and solutions are also discussed for planning and engineering of DR island systems [9]. The regulations are clearly defined for the main contents of IEEE 1547.4 as follows: Power Flow, Voltage, Frequency, Single PCCs or Multiple PCCs (need coordination), Fault Protection, Load Requirements, Reserve Margins, Adequate DR Power, Quality, Transients.

IEC/TS 62257-9-2

The International Electrotechnical Commission (IEC) is a well-known organisation for an international system of standards. IEC publishes International Standards with the aim of promoting international co-operation concerning standardization in the electrical and electronic fields. IEC 62257-
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9-2 is a part of IEC 62257 series entitled " Recommendations for small renewable energy and hybrid systems for rural electrification". This section is " Recommendations for small renewable energy and hybrid systems for rural electrification – Part 9-2: microgrids", which covers a technical specification, which was prepared by IEC technical committee 82: Solar photovoltaic energy systems. The main mission of IEC 62257-9 is to address requirements for the design and the implementation of microgrids to ensure the safety of persons and property and their satisfactory operation in rural areas [10]. Important contents of IEC/TS 62257-9-2 were addressed as, Voltage drops limitations Requirement for electric shock protections Requirement for overcurrent protections Selection and erection of equipment Verification procedures of before commissioning

SEMI F47

Semiconductor Equipment and Materials International (SEMI) F47 standard entitled " Specification for Semiconductor Processing Equipment Voltage Sag Immunity" is an industrial standard defining requirement for voltage sag immunity, which includes restriction for depths and durations. It is claimed that equipment complies with SEMI F47 is more reliable, and more productive. The SEMI F47 Standard is taken into account for microgrids studies as the durations for separating microgrids from main grid need to be limited to less than 50ms, which is equivalent to 3 cycle of 60Hz system. The requirements of this standard do not conflict with known countries generic equipment regulations or well-known standards. Detailed requirements for each type of equipment listed below are defined in SEMI F47 [11] with requirement of voltage sag is visualised in Fig. 2, Etch equipment (Dry & <https://assignbuster.com/micro-grid-operation-and-protection-engineering-essay/>

Wet) Film deposition equipment (CVD & PVD) Thermal equipment Surface prep and clean Photolithography equipment (Stepper & Tracks) Chemical Mechanical Polishing equipment Ion Implant equipment Metrology equipment Automated test equipment Figure : The SEMI F47 Voltage Sag Ride-Through Curve

2. 4 Operation modes

According to IEEE 1547.4 standard, there are four main operation modes of microgrids,

1. Area EPS-connected mode (normal operation)

This mode is often called Connected Mode, in which microgrids are connected to area local utility grid EPS and it is a normal operation.

Distributed energy resources shall operate in accordance with IEEE Standard 1547-2003 unless agreed upon by the area EPS operator. Loads in microgrids are partially supplied by local DERs and electricity from main grid during peak hours or at night. At off-peak hours, energy may be transferred from microgrids to main grid and they play a controllable active load within the whole network.

2. Transition-to-island mode

Transition-to-island mode happens during the transient state of microgrids moving from this state to other stable state due to a short-circuit action (unscheduled events) or as planned (scheduled events). Unscheduled events may lead to the unstable situation and load shedding procedure may be applied if necessary. For scheduled events, the time and duration of the

planned transitions are well defined and agreed upon by all parties involved. Load are unlike to be shed with this event.

3. Island mode

This mode is often called Stand-Alone Mode, in which DERs supply majority of local electricity demand. The unserved load need to be shed due to the shortage of supply. During the island mode condition, transient stability should be maintained for load steps, DR distributed energy resource unit outage, and island faults. Protective device coordination should be maintained in both area EPS-connected and islanded operation. All potential faults within the island should be detected and cleared during island mode if they were able to be detected and cleared when in area EPS-connected mode. Adaptive relaying may be implemented to provide adequate protection for a variety of system operating modes. There should be sufficient monitoring to operate and understand the status of the island. If there are multiple distributed energy resourceDR units in the DR islanded system, their operation should be managed and coordinated to effectively meet the needs of the island.

4. Reconnection mode

This mode happens after a disconnection event of microgrids. Requirements for this mode is clearly defined in well-known standards, such as ANSI/NEMA C84. 1-2006 or each country Connection Rules or Codes. Resynchronisation is needed with the agreed frequencies between microgrids and main grid. This procedure may be actioned automatically by coordinator [12] or

manually by staff. In practical industry, two main operation modes that are greatly paid attention are Connected Mode and Isolated Mode.

2.5 Type of short circuit in microgrids

Play a similar role to ordinary network, microgrids may have several types of short circuit. Among them, there are two common ones,

Single Line to Ground Fault

This situation happens when any phase A, B or C of system connects with ground accidentally by conductors, such as plants, animals or lightning. This type of short circuit may lead to shutting down power and/or equipment malfunctions, fire and electric shock, damaging equipment. Furthermore, it poses potential health and safety risks to personnel due to hazardous areas around short circuit location. For those reasons, this type of short circuit needs to be located and isolated as soon as it happens. In order to understand line to ground short circuit, the nature and equivalent circuit of this type is shown in Fig. 3. Figure : Line to Ground short circuit
In general, it is assumed that phase A contain a short circuit location through an impedance Z_f . The other currents flowing in other phases are,*
MERGEFORMAT ()* MERGEFORMAT ()Relation between voltage and short circuit current,* MERGEFORMAT ()Sequence frame of short circuit current*
MERGEFORMAT ()Consequently,* MERGEFORMAT ()

Line to Line fault

Here at least two phases out of three phase A, B and C are connected via conductor accidentally as in Fig. 4. The relation of currents within phases are shown as,* MERGEFORMAT ()* MERGEFORMAT ()Sequence frame of short

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circuit current* MERGEFORMAT ()Relation between voltage and short current,* MERGEFORMAT ()Consequently,* MERGEFORMAT ()Figure : Line to Line short circuitUsing equivalent circuits, calculation approaches are then used to define the short circuit level (current and power) for a given microgrid. There are two main updated methodologies: Sequence Frame and Phase Frame. These approaches will be discussed later.

2. 6 Earthing System Configurations

Earthing systems are greatly important for microgrids in terms of protection system design and implementation. In order to address different types of earthing systems, the following abbreviations are used: T - Direct connection to earthN - NeutralC - CombinedS - Separate andI - Isolated from earthEach earthing configuration mainly uses a combination of two letters or more: The first one denotes how the transformer neutral (supply source) is earthed while the second one denotes how the metalwork of an installation (frame) is earthed. The third and fourth letters indicate the functions of neutral and protective conductors respectively [13]. Possible earthing configurations for microgrids are listed and figured as following, TT: Transformer neutral earthed and frame earthed. TN: Transformer neutral earthed, frame connected to neutral. IT: Unearthed transformer neutral, earthed frame. The TN system includes three sub-systems: TN-C, TN-S and TN-C-S as in Fig. 5, as discussed in the following sub-sectionsFigure : TN Earthing System(a) TN-C Configuration; (b): TN-S Configuration; (c): TN-C-S ConfigurationFigure : IT Earthing System ConfigurationFigure : TT Earthing System Configuration

2. 7 Symmetric components approach

Symmetrical components (positive sequence, negative sequence, and zero sequence) are used to analyse power system operation during unbalanced conditions such as: Short circuit caused by faults between phases and/or ground, Open phases, Unbalanced impedances. Detailed assumption and calculation steps of these methodologies are well defined in textbooks and studies [14-22]. Only vital notes of this method are emphasized below.

Definition of sequences

The positive sequence set consists of the balanced three-phase currents and line-to-neutral voltages supplied by the system generator. The sequence currents or sequence voltages always exist as a set of three phasors, never alone or in pairs. The negative sequence set is also balanced with three equal magnitude quantities at 120 degrees apart but with the phase rotation or sequence reversed. For the negative sequence set, again the sequence currents or sequence voltages always exist in full set with three's components, never alone or in pairs. The members of the zero-sequence set of rotating phasors are always equal in magnitude and always in phase. Once again, if zero sequence currents or zero sequence voltages exist, they must exist in all three phases, never alone or in one phase. The sequences for main power system components are listed as follows,

Transmission Lines

For transmission lines, the phase sequence of the current does not change the impedance encountered, so positive sequence impedance equals

negative sequence impedance; $X_1 = X_2$. For estimating open lines $X_0 = 3$ or 3.5 times X_1 is commonly used

Transformers

In transformers, it is similar to transmission line, positive sequence impedance equals negative sequence impedance; $X_1 = X_2$. Zero sequence for transformers is equal to the positive & negative sequence and is the transformer leakage impedance, except in core-type transformers where $X_0 = .85$ to $.9$ times X_1 . Rotating Machines Generators do not generate negative sequence currents, but negative sequence can flow in their windings. For rotating machines, except for calculating faults very near machine terminals, can assume $X_0 = .85$ to $.9$ times X_1 . Thus, zero sequence impedance of generators is low and variable depending on winding design.

3

CURRENT WORKS STATE OF ART AND & MOTIVATION

This section covers current state of art and remarkable contributions all over the world in recent year to microgrids. These works will be carefully investigated with the aim finding gaps and needs for further development and improvement. Research motivation and targets will be stated later on.

3.1 Groups doing research on microgrid worldwide

With the aim of sharing experience, peer reviewing, supporting among research groups, it is essential to have an acknowledgement of works,

progress and contributions so far of other groups. Main research groups and <https://assignbuster.com/micro-grid-operation-and-protection-engineering-essay/>

organisations from Europe, United States, Japan, and Canada working on microgrids may be listed as [13],

Europe

There are two major research efforts with international level, which devoted exclusively to microgrids. The 5th Framework Programme (1998–2002) for microgrids: Large Scale Integration of Micro-Generation to Low Voltage Grids activity was funded at €4.5 million. This Consortium is led by the National Technical University of Athens (NTUA), including 14 partners from seven EU countries, including utilities such as EdF (France), PPC (Greece), and EdP (Portugal); manufacturers, such as Em Force, SMA, GERMANOS, and URENCO; plus research institutions and universities such as Labein, INESC Porto, the University of Manchester, ISET Kassel, and Ecole de MinesAdvanced Architectures and Control Concepts for More microgrids within the 6th Framework Programme (2002–2006) was funded at €8.5 million. This is led by NTUA, comprises manufacturers, including Siemens, ABB, SMA, ZIV, I-Power, Anco, Germanos, and EmForce; power utilities from Denmark, Germany, Portugal, the Netherlands, and Poland; and research teams from Greece, the United Kingdom, France, Spain, Portugal, and GermanyMain achievements from these projects are DER models for steady-state and dynamic analysis; philosophies of islanded and interconnected microgrids; control algorithms; strategies for local blackstart; grounding and protection approaches. Demonstration sides were also built in Greece (The Kythnos Island Microgrid), Netherland (Continuon's MV/LV facility) and Germany (MVV Residential Demonstration at Mannheim-Wallstadt) for testing purposes.

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United States

Microgrids research program, which is supported by the U. S. Department of Energy (DOE) under the Office of Electricity Delivery and Energy Reliability (OE), and by the California Energy Commission (CEC), have continuously expanded for years. Most important projects are carried out in US are, The project conducted by Consortium for Electric Reliability Technology Solutions (CERTS) since 1999 to address implications for power system reliability of emerging technological, economic, regulatory-institutional, and environmental influences. A two-year project was funded by DOE and General Electric (GE) a second with approximately US\$4 million. This research aims to develop and demonstrate a microgrid energy management (MEM) framework for a broad set of microgrid applications that provides a unified controls, protection, and energy management platform.

Japan

Main projects at Japan are, NEDO Mmicrogrid Projects: The Aomori Project in HachinoheThe Aichi Project near the Central Japan AirportThe Kyoto Project at Kyotango

Canada

Microgrids researches in Canada are focused on medium voltage carried out by universities in collaboration with the electric utility industry, manufacturers, and other stakeholders in distributed energy resources integration and utilization.

3. 2 Potential earthing systems for microgrids

Normal operation modes of microgrids has been paid significant attention of researchers in recent years via intensive works from modelling to control stages for both Connected Mode and Islanded Mode [23-30]. The transient mode and reconnection mode, however, were not fully considered. These modes play important roles in terms of designing and controlling protection devices. Thus, a better understanding of transient state of microgrids will be a key aspect improving reliability and stability. This research aims to further studies conventional earthing systems for microgrids, addresses main protection basics to explore approaches developing novel protection systems for advanced microgrids. Any fault in a given microgrid may generate may cause ground potential rise leading to hazards for personnel and damage to equipment. Thus earthing systems of the distributed energy resources and the transformers connecting the microgrid to the utility network must be carefully analysed and appropriately regulated. This earthing system need to be adaptable for both connected and islanded modes operation. Via current studies and standards mentioned above, TN-C-S and TT earthing systems are currently considered effective solutions for neutral earthing of a LV microgrid and dDistributed energy resources in both normal grid connected operation and islanded operation [31]. Moreover, TN-C is also studied and approved as a sufficient earthing system for microgrids in general [10]. Similar results are concluded for TN earthing systems [32]. It is stated that TN is the most suitable earthing system for both connected mode islanded mode thanks to the following advantages [13]: Providing a return path for faults in the LV gridLower earthing resistance of conductorTouch voltages are generally

smaller than in TT earthing systems if insulation faultNo overvoltage stress on equipment insulationTN-S system has the best Electromagnetic Compatibility (EMC) properties for 50 Hz and high frequency currents, certainly when LV cable with a grounded sheath is applied. TN earthing system could work with simple over current protection. High reliability of disconnection of a fault by overBased on these earthing system, protection schemes are proposed and simulated for AC systems [33] andor DC systems [34] or control and general intelligent method for protection is also considered [35]. The lack of practical experiment of these approaches need to be further verified. Suggestion for fast operating circuit breakers or static switches are also been suggested [36] or [37]. These methods can be applied to only limited point with selective objects in microgrid. For verification purpose, TN earthing system and related systems need to be carefully considered and simulated to consolidate past works conclusion.

3. 3 Current microgrids challenges

Low short-circuit current

It is crucial for protection system to be adaptable to both connected and islanded operation mode of microgrids. In connected mode, main grid will contribute energy to short circuit location with large current enables protection devices to locate and to trip effectively. In islanded mode, however, only distributed generation contribute energy to short circuit current via power electronics in most of cases. This fault current flows through inverters is limited by the ratings of the silicon devices to around 2p. u. rated current [38] [39] [40] to 5p. u [41]. Small fault current in islanded

inverter based microgrids may not have adequate magnitudes to trip the fault if conventional mechanism of over-current protection is used.

Power direction from both sides at a node

The fact that microgrids may contain two or more distributed generators leads to main challenge for protecting a microgrid due to both directions of power flow in each feeder. The closer local load feeder is, the more usual this situation happens. It is obvious that, in conventional electrical systems, power always flows in one direction, from the distribution substation towards the loads. Bi-direction or multi-direction of power flow make traditional protection device less selective and may fail to operate [38]. This issue can be solved with a development of an advanced class of protection devices with high accuracy and selectivity characteristics. As in Fig. 8, load L1 can receive energy from both generator A1 or A2 as the sources locate in both sides of the load and therefore, power flows in opposite directions from the two sources towards the load feeder [38]. Figure : Protection scheme for Micro-Grids

Harmonics issues

There are two main causes for harmonics within microgrids. Firstly, electronically switched loads can inject harmonic distortions for both load voltage and current. Secondly, inverters with different switching schemes will contribute to overall total harmonics distortion. In order to improve quality index, suitable control techniques need to be applied to reduce distortion level. Swarm optimisation based harmonic optimisation technique, sine PWM technique and a combination of both are proposed [42]. Selective

harmonic elimination method is also considered [43] [44] for decades. These works are carried out based on Matlab/Simulink simulation and lab experimental to obtain results. Testing on site need to be carefully studied to verify their achievements.

3. 4 Tools selection for microgrids analysis

In order to analyse microgrids in different operation modes, it is necessary to explore a suitable tool that can cover both balanced and unbalanced analysis for steady state as well as transient state. A study of three well-known software packages with friendly interactive interfaces PSCAD, DigSilent Power Factory and PSS/Adept, is carried out. Main function of these tools are tabulated as, FeaturePSCADDigSilentPSS/AdeptBalance/Unbalance Power Flow

Yes

Yes

Yes

One/Three Phase Line

Yes

Yes

Yes

One/Three Phase Load Model

Yes

Yes

Yes

Full Coupling Mutual Impedance

Yes

Yes

-

Unbalanced Load Model

Yes

Yes

Yes

Power Electronics ElementYesYes

-

Fault AnalysisYesYesYesTransient start analysisYesYesLimitedDC Load

FlowLimitedYes

-

Small signal analysis (eigenvalues)YesYes

-

Static and dynamic voltage stabilityYesYesVAR/STATCOMYesLimited

-

Wind/Solar PanelYesLimited

-

Harmonics, flicker and resonance analysis Yes Yes Yes Tie Open Point

Optimization Limited Yes Yes Capacitor Placement

Optimization Limited Yes Yes Protection and coordination Yes Yes Yes Power

System Simulator Advanced Distribution Engineering Productivity Tool

(PSS/ADEPT) is a distribution system analysis program developed by Power Technologies, Inc. (PTI) for planning, designing, and analysing distribution systems. Although another software package distribution (PSS®SINCAL) has been produced by PTI, it is still a popular software package for distribution operator all over the world [45]. PSS/Adept has a friendly graphic user interface for engineers to add, edit or remove all electric device models on workspace. From the point of view of operation engineers, it is a helpful tool for power flow analysis, short-circuit analysis, motor starting analysis, capacitor optimization, tie open point optimization, and predictive reliability analysis. However, if further analytical consideration is required, such as fully coupled impedance matrix in three phase system, it may not be a promising candidate. PSCAD® is a simulation software for the design and verification of power systems. PSCAD® is also known as PSCAD®/EMTDC™ because EMTDC™ is the simulation engine, which is now the integral part of PSCAD® graphical user interface. PSCAD® is a powerful analyzing tool for simulating time domain instantaneous responses in both electrical and control systems with visual online controllers for user to adjust the parameters while running [46]. DigSilent Power Factory is a transmission and distribution network analysis tool with the capability to simulate wide range of power electronic devices, renewable energy plants and fully coupled

conductor models [47]. It is a helpful combination of easy-to-use software for engineers (i. e., PSS/ADEPT) and a novel tool for researcher (i. e., PSCAD). For microgrids studies, this software is an effective potential tool and hence this software is chosen for further work in this research.

3. 5 Proposed methodology for research

This research aims to study microgrids protection principles and propose a novel protection mechanism for microgrids in both connected and islanded modes. To reach this target, a clear understanding of components response to transient states including transience to islanded mode and reconnection mode is a required condition. Typical and/or standard microgrids will firstly simulated and analysed using selected tool, i. e. Digsilent Power Factory. Characteristics of well-known wind turbines technologies, inverters control and switching schemes, solar panel interfaces are background need to well prepare for higher studies. Figure 9 shows a typical microgrid containing 16 buses with different generation technologies, such as solar power, wind turbine, synchronous generator supplying to balanced and unbalanced loads. Figure : A typical microgrid for transient study Response of double-fed induction machine regarding torque, mechanical speed, wind speed, power capacity, currents and behaviour of inverter at solar power site will be explored and analysed. Additional standard microgrids from CIGRE and practical networks will be taken into account next stage of research.

4

CONCLUSION

There is no doubt that microgrids have been playing an important role for industry in terms of a promising solution to global warming and urgent environmental concerns. Although they were introduced recently, researchers are increasingly paying attention on them worldwide with various supporting partners. In the meantime, only two out of four normal operation modes of microgrids are intensively studied. The two remaining modes Transition-to-island and Reconnection need to be further explored as they are the crucial keys for improving reliability and power quality of microgrids. Furthermore, conventional protection systems in current distribution networks, which were designed to operate at high fault-current levels, are no longer applicable for this new type of network. In order to develop new protection methods and more advanced class of protection devices with higher level of selectivity, speed and reliability satisfying future microgrids requirements, it is necessary to investigate characteristics and behaviours of main components within microgrids during transient states. For above reasons, first step of this research will focus on collating and studying vital components of microgrids including but not limited to double-fed induction generators, inverters with various switching scheme, electronics interface of solar power. Transition-to-island and reconnection modes of microgrids are then carefully considered. After that, an effective computer aid software will be utilised to model and to analyse simulation results before carrying out experiments in labs for verifying purposes. The

final aim of this project is to use real typical networks for testing proposed techniques and justifying methodology if needed.