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MICROGRIDS PROTECTION SCHEMES, CHALLENGES AND STRATEGIES

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SCOPE

The main purpose of this work is to present a review of various protection schemes and solutions for Microgrids (MGs) both in grid-connected and islanded mode of operation.

CONTENTS

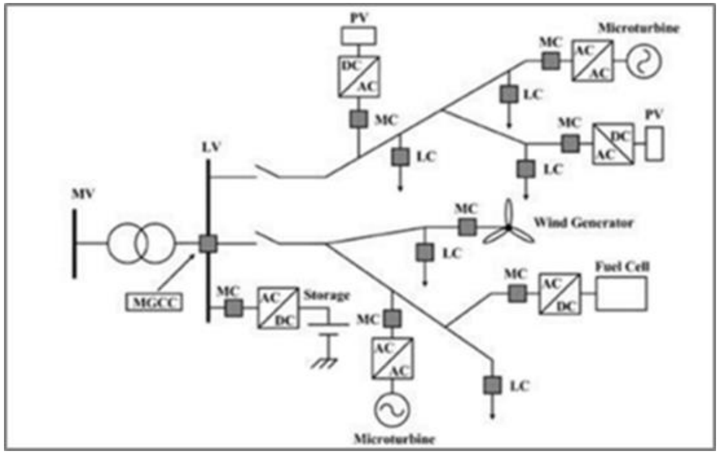
- The presence of Distributed Generation (DG) units close to demand can offer several economic, operational, technical and environmental benefits.

- The coordinated control of DG units in a Microgrid (S-MG) structure allows the full exploitation of them.

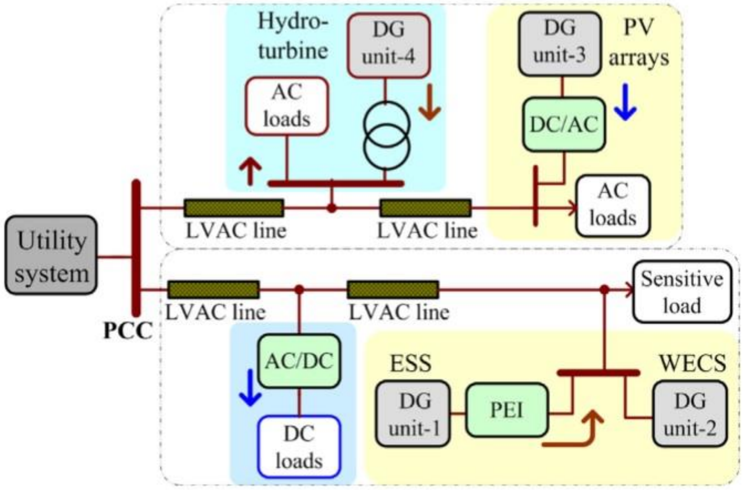
- A Microgrid also characterized as the “building block of Smart Grid”, is perhaps the most promising, novel network structure. The organization of a MG is based on the control capabilities over the network operation offered by the increasing penetration of Distributed Energy Resources (DER) including Microturbines (MT), Fuel Cells (FC), Wind Turbines (WT), photovoltaic arrays (PV), together with storage devices, such as flywheels, energy capacitors, batteries, controllable (flexible) loads and Electric Vehicles (EVs), at the distribution level (Medium and Low Voltage).

- Controlled and uncontrolled loads, DG units and storage devices operating together in a coordinated manner with controlled power electronic devices which are integrated with protective devices. They can be operated based on the principles of the AC power systems (AC-MG) or DC power systems (DC-MG).

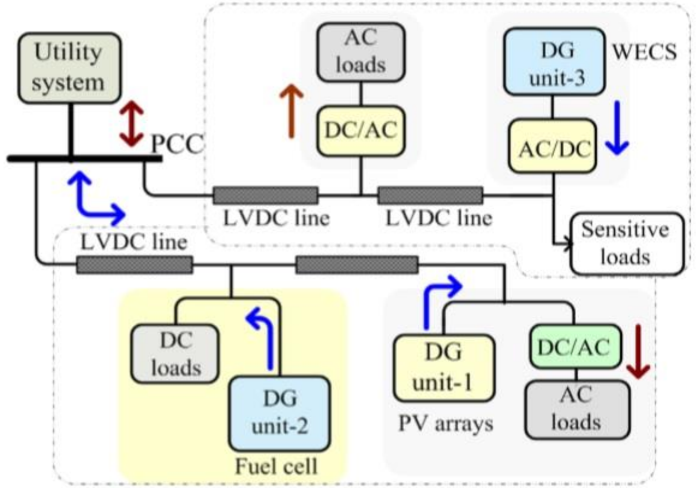
- System protection within the MG components and short-circuit currents limitation can be achieved through a proper coordination of the DG units.



Structure of the Microgrid
MGCC-Microgrid System Central Controller,
LC-Local Controller,
MC-Micro Source Controller



AC microgrid structure with the DG units and mixed types of loads



Concept of a DC microgrid system with the DG units and mixed types of loads

One of the prominent challenges, which hinder wide adaptation of the MG technology, is AC and DC MGs Protection.

There are some approaches for improving the protection performance:

A. ***Technical Challenges in AC Microgrid***

   i. **MG operation modes**. In grid-connected mode, utility and DGs contribute to fault current, while in islanded-mode, fault currents only are fed by DGs. As a result, sets of settings for MG relays are required to cope with the dynamic behavior of DERs in MG.
   ii. **DERs impacts on Protective Devices (PDs)**. DER locations and fault currents would determine precise relay settings.
   iii. **MG topology effects on PDs coordination**. MGs have dynamic topologies. Regardless of the reasons behind MG topology changes, this phenomenon could impact on current directions and magnitudes, and would lead to mis-coordination of PDs.
   iv. **Grid code compliance**. High penetration levels of renewable energy sources in power system has led to elaboration of specific technical requirements in the grid codes. The goal of modification in the existing grid codes is to improve stability of the grid

There are some approaches for improving the protection performance:

A. Technical Challenges in AC Microgrid

v. **Standardization and communication**. To minimize the number of customers as well as DGs affected by faults and disturbances, a high-speed communication and an adaptive multi-criteria algorithm are required. The fast and reliable communication could monitor a small change in the grid configuration.

B. Technical Challenges in DC Microgrid

Except the above, there are some additional challenges are required to be addressed.

i. **Grounding**. The main purpose of grounding is to detect the ground fault. In order to design the grounding system, two contradictory requirements must be taken into account: a) Minimize DC stray current, b) Maximize personnel safety by minimizing the common mode voltage.

ii. **No zero-crossing current**. In AC system, mechanical Circuit Breakers (CBs) disconnect circuit when currents cross zero at every half-period; however, in DC system CBs there are no zero crossings. And hence, currents have to be forced to zero by additional means. In addition, low DC impedances make DC fault levels very high.

There are some approaches for improving the protection performance:

Solutions for AC Microgrid Protection

i. **Adaptive protection**. After advent of MGs, conventional overcurrent protection relays encounter selectivity and sensitivity issues due to different levels of fault during islanded and grid-connected modes. One of the promising solutions is adaptive protection technique.

ii. **Current limiting**. One of the effective approaches to confine fault current is current limiting. This goal can be achieved through various ways.
   - *a) Virtual impedance*
   - *b) Fault current limiter*

iii. **Fault detection**. Fault or islanding detection could have a numerous contributions (i.e. facilitate applying adaptive protection and active management) to the grid. Basically, islanding detection methods are classified into three main categories: active, passive, and communication-based approaches. As a result, the promising islanding detection methods must meet the smart grid requirements.

iv. **Standardization**. To achieve the highly cooperative relationship of different components of the grid, standardizations for implementation of smart grids as well as a high reliable and cost-effective communication are required. The international electrotechnical commission (IEC) Smart Grid Standardization Roadmap [50] suggests various core standards for the realization of the smart grids

There are some approaches for improving the protection performance:

A. Solutions for AC Microgrid Protection

v. **Self-healing actions**. Self-healing is an ability to allow resilience and fast recovery of the power system in response to the fault conditions have been envisioned. Self-healing usually refers to reconfiguration, load shedding, or controlling the dispatchable generators' output powers.

B. Solutions for DC Microgrid Protection

i. **Grounding systems and fault detection**. Due to the low ground current, detection of fault is difficult. Furthermore, second ground fault in another pole results in line-to-line fault causes a significant damage. As a result, detection in ungrounded system is a vital action toward improving ungrounded or even grounded system performance.

ii. **Current limiting methods**. Due to no zero-crossing current in DC MG, new approaches or physical circuit are necessary for DC MGs. Some of the promising solutions are as follows:

   a) *Z-source circuit breakers.*
   b) *Virtual impedance.*

SOME INTERESTING FIGURES OF DC AND AC MICROGRIDS PROTECTION _1

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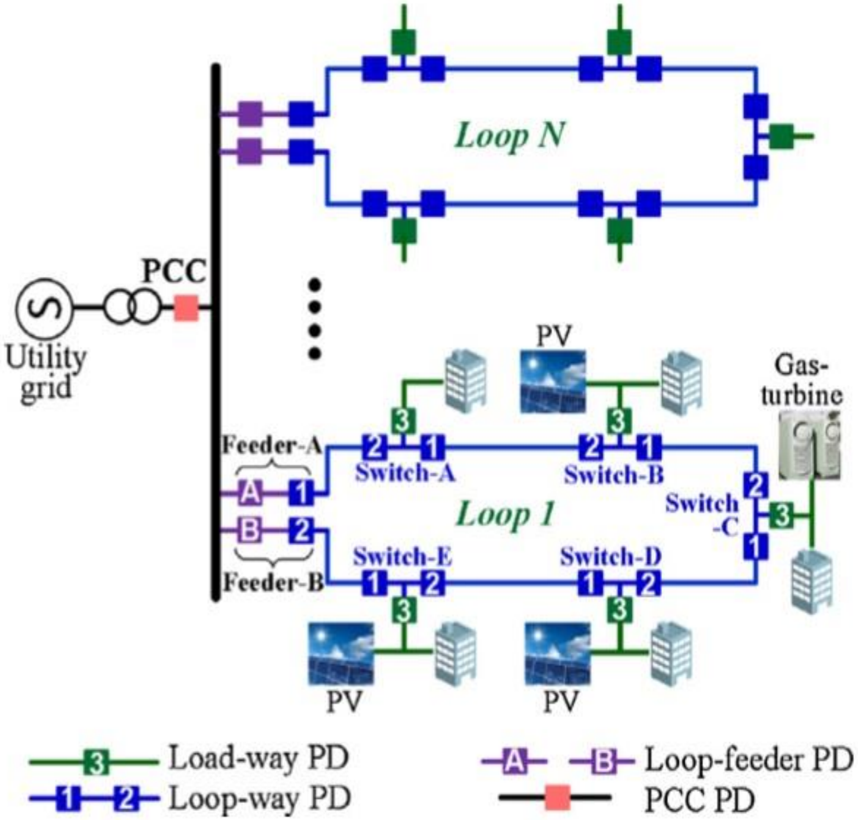
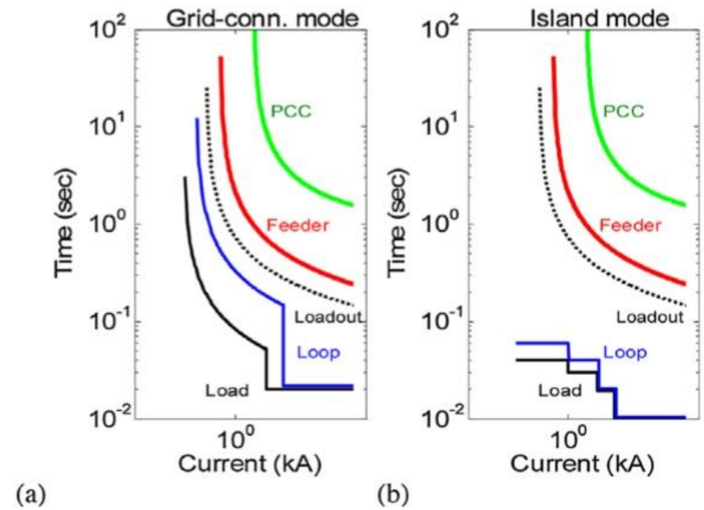
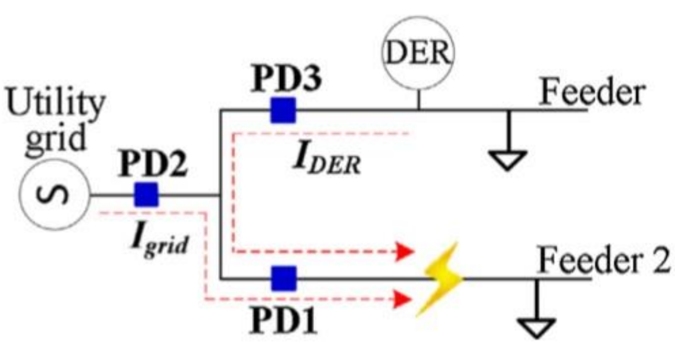


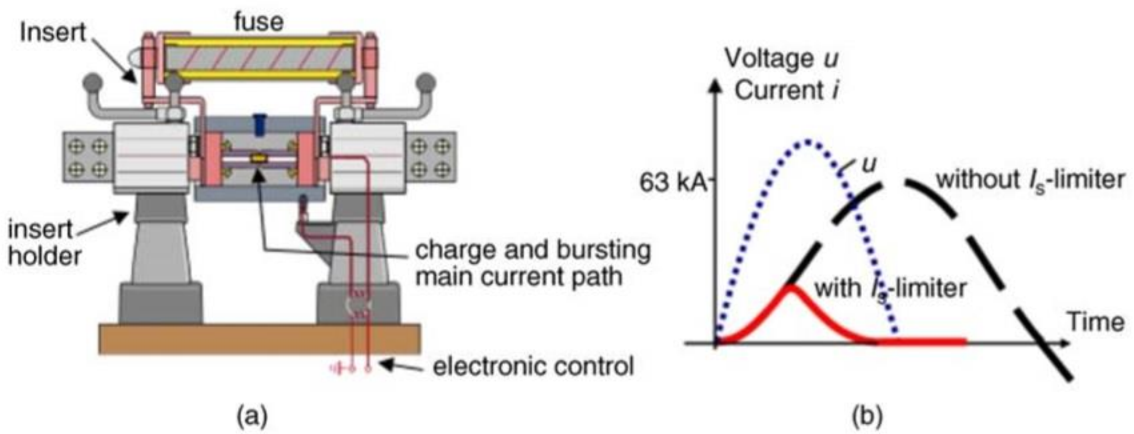
Protection system for a high-reliability MG operation



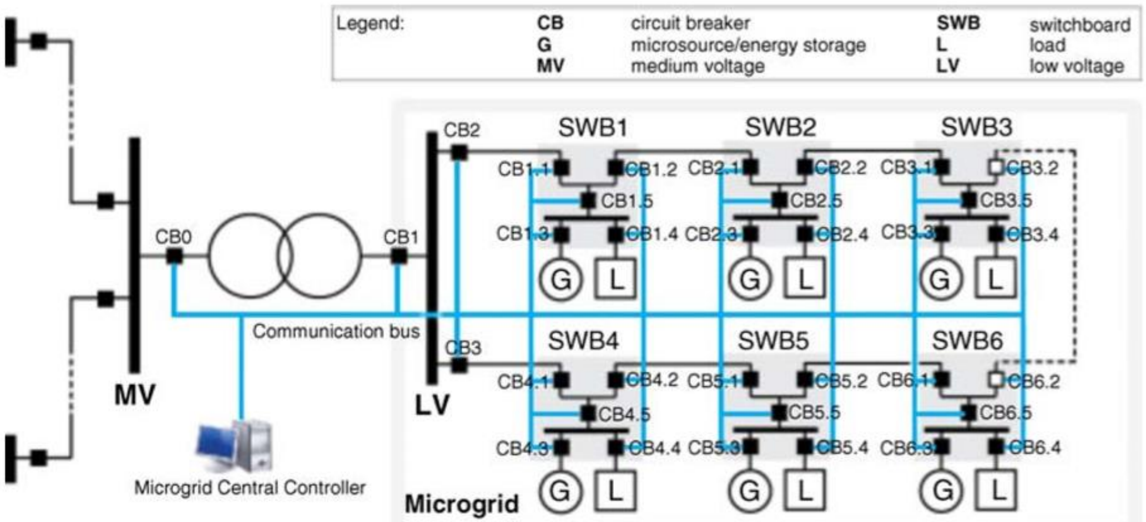
Relay Time Over Current (TOC) Characteristics in (a) grid-connected and (b) Island modes



DER operation of protective devices



Is-limiter with insert (a) and its current limiting effect (b)



A centralized adaptive protection system

- AC and DC MGs are confronting the minor or major protection challenges.

- Consequently, different layers in the smart grid must be developed and reinforced to fundamentally address the current and upcoming challenges of MGs protection.

Control and protection systems

In AC and DC MGs, protection scheme must corporate with control system, because of some issues such as Low Voltage Right Through capability, reconfiguration and self-healing, and approaching current to zero before CBs operations in DC MG.

This integration is achieved under the well-designed communication and information infrastructures; moreover, MGs move toward distributed structure, thus other new control and communication concepts have to be considered to facilitate operation of control systems in distributed manner. These issues are multi-agent system (MAS), distributed control, network control, corporative control, consensus algorithms, and sparse communication.

Control and Protection Systems

- ✓ Recently, the solid-state transformer (SST) has gained increasing importance in the future power distribution system.

- ✓ The SST designed for the purposes of power flow control, voltage sag compensation, fault current limitation, seamless transition between the microgrids' two operation modes, isolation, active power management of the DC microgrids, and providing dc and ac interface.

- ✓ As a result, the SSTs are suitable candidates to improve the microgrids performance in term of energy transfer, protection and control. Although, significant progresses have been made in the SST technologies, the cost and reliability issues of the SST are the main issue that hampers it into the market.

- ✓ One another technology used to cope with the problem of non-zero crossing current is the Z-source circuit breaker. However, some of its drawbacks such no prolonged protection and no common grounding connections are required to be addressed.

CONCLUSIONS

- ❑ Microgrid is considered as a main part of smart grid.
- ❑ Protection is the one of the most tough challenges in MGs.
- ❑ This work presents various challenges in AC and DC MGs and addressing these challenges by several approaches.
- ❑ Finally, it investigates the future trends and their related open issues in order to pave the way of implementation of protection in MGs.

Thank you for your attention!