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Technical Investigation on Microgrid and Power Quality Impact

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Abstract— A microgrid is a hybrid power system consists of several distributed generation resources and local loads, which provide the solution to supply premium power to remote or specific areas. A microgrid is electrically isolatable from the utility macrogrid and would often have sufficient cumulative capacity to meet the needs of those within in, although most microgrid concepts also specify a utility backup. Some microgrids could operate as full-time islands, while others could operate as part of the macrogrid during normal operation and only separate into an island during service interruptions. However, some undesired effects are accompanied with their installations and operations, such as imbalance, voltage fluctuation, and harmonics. To the aspect of voltage quality, the switching on and off of the distributed generation resources may cause power fluctuation, hence the associated power quality disturbances are produced and affect the connected power system. This paper presents about the concept of microgrid and power quality issues associated with it and its remedies.

Index Terms— Microgrid, Power Quality, Harmonics, Power Flow Control, Stability.

1 Introduction

A typical microgrid would comprise a cluster of generators and loads capable of operating in a coordinated fashion autonomously or semi-autonomously from the macrogrid. It could also include energy storage devices. The cluster would most likely exist within a small, dense group of contiguous geographic sites, although its components could be dispersed and share electrical energy through a distribution network [1]. Generators and loads within a microgrid would be placed and coordinated to minimize the cost of serving electric (and, if combined heat and power (CHP) systems are employed, heat) demand given prevailing market conditions, while continuing to operate safely and maintaining power balance and quality. This pattern of power generation and consumption is distinctly different from existing power systems in that the sources and sinks within a microgrid can be maintained in a balanced and stable state without active external control or support. Figure 1 shows the block diagram of microgrid.

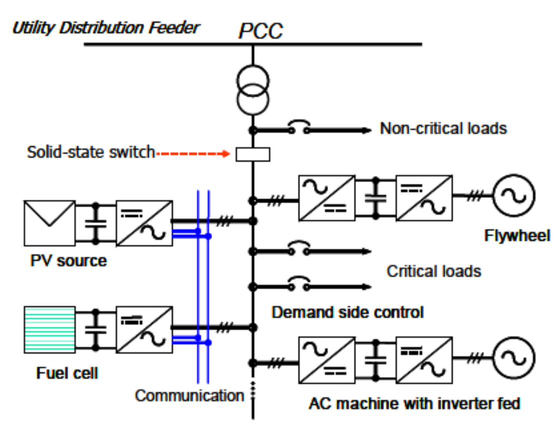

Fig. 1. Block Diagram Microgrid.

Microgrids supplied by renewable energy sources (RES) are increasingly studied due to their insignificant environmental impact, concerning the classical power plants. The connection of small generation units (tens of kilowatts) in low voltage networks tends to be a more reliable solution [2]. A microgrid can be defined as a low-voltage network with its loads and several small modular generation systems connected to it, providing both power and sometimes heat (combined heat

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and power – CHP) to local loads. An islanded microgrid must have its own resources to maintain the power quality, mainly the voltage and frequency rated values. The voltage variations depend of the system reactive power, while the frequency depends of the system active power balance.

2 TECHNICAL AND ECONOMICAL SUPPORT OF MICROGRID

The development of Microgrid is very promising for the electric energy industry because of the following advantages [3]:

1. Environmental issues

It is needless to say that Microgrids would have much lesser environmental impact than the large conventional thermal power stations. However, it must be mentioned that the successful implementation of carbon capture and storage (CCS) schemes for thermal power plants will drastically reduce the environmental impacts. Nevertheless, some of the benefits of Microgrid in this regard are;to Reduction in gaseous and particulate emissions due to close control of the combustion process may ultimately help combat global warming.Physical proximity of customers with microsources may help to increase the awareness of customers towards judicious energy usage.

2. Operation and investment issues

Reduction of physical and electrical distance between microsource and loads can contribute to: Improve reactive support of the whole system, thus enhancing the voltage profile, Reduction of T&D feeder congestion and losses to about 3%, Reduction/postponement of investments in the expansion of transmission and generation systems by proper asset management**.**

3. Power quality

Improvement in power quality and reliability is achieved due toDecentralization of supply, Better match of supply and demand.Reduction of the impact of large-scale transmission and generation outages, Minimization of downtimes and enhancement of the restoration process through black start operations of microsources.

4. Cost saving

The following cost savings are achieved in Microgrid.A significant saving comes from utilization of waste heat in CHP mode of operation. Moreover, as the CHP sources are located close to the customer loads, no substantial infrastructure is required for heat transmission. This gives a total energy efficiency of more than 80% as compared to a maximum of 40% for a conventional power system.

Cost saving is also effected through integration of several microsources. As they are locally placed in plug-and-play mode, the T&D costs are drastically reduced or eliminated. When combined into a Microgrid, the generated electricity can be shared locally among the customers, which again reduces the need to import/export power to/from the main grid over longer feeders.

5. Market issues

The following advantages are attained in case of market participation development of market-driven operation procedures of the Microgrids will lead to a significant reduction of market power exerted by the established generation companies.

The Microgrids may be used to provide ancillary services. Widespread application of modular plug and play microsources may contribute to a reduction in energy price in the power market. The appropriate economic balance between network investment and DG utilization is likely to reduce the long-term electricity customer prices by about 10%.

DRAWBACKS OF MICROGRID

Voltage, frequency and power quality are three main parameters that must be considered and controlled to acceptable standards whilst the power and energy balance is maintained. Electrical energy needs to be stored in battery banks thus requiring more space and maintenance.

Resynchronization with the utility grid is difficult. Microgrid protection is one of the most important challenges facing the implementation of Microgrids. Issues such as standby charges and net metering may pose obstacles for Microgrid. Interconnection standards need to be developed to ensure consistency.

3 MICROGRID ON POWER QUALITY ISSUES

Microgrid can operate in both modes of operations that is grid connected mode and islanded mode. The increased penetration of distributed generation in micro grid system poses several technical problems in the operation of the grid such as steady state and transient over & under voltages at point of connection, protection malfunctions, increase in short circuit levels and power quality problems. The coexistence of multiple energy sources which have versatile dynamic properties and electrical characteristics have impact on safety, efficiency, control and stability of micro grid. Technical issues associated with operation of micro grid are interconnection and the islanding mode. Interconnection of micro grid with main grid is complex; complexity in interconnection is affected by the types of power generation number of generating

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sources, location of points of interconnection and level of penetration of micro grid system with main grid. The major issues in microgrid are,

POWER FLOW CONTROL

Active Power Control in Each Micro Sources

During islanded (autonomous) operation, when an imbalance between load and local generation occurs, the grid frequency drifts from its nominal value. Storage devices (flywheel) keep injecting power into the network as long as the frequency differed from the nominal value. Micro turbine and fuel cell are controllable sources which the power output can be controlled. A PI controller (being the input of this controller the frequency deviation) which acts directly in the primary machine (*Pref* of fuel cell and micro turbine) allows frequency restoration. After frequency restoration, storage devices will operate again at the normal operation point (zero active power output). This controller can not apply to wind turbine and photovoltaic panels because they are uncontrollable sources and their output power depend on wind speed, irradiance and ambient temperature. Figure 2 shows the PI controller block diagram used to control the output power of fuel cell and micro turbine [4].

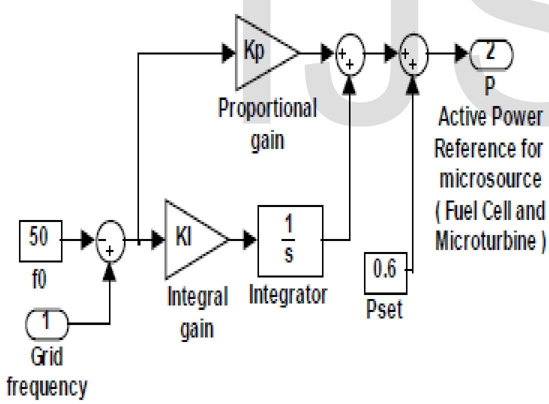

Fig. 2. Control of active power in controllable micro source.

Voltage and Reactive Power Control

In Figure 3, represents the adopted voltage control strategy. By knowing the network characteristics, it is possible to define the maximum voltage droop. To maintain the voltage between acceptable limits, the voltage sources inverter (VSI) or Vf inverter connected to the flywheel will adjust the reactive power in the MG. It will inject reactive power when voltage falls from the nominal value and will absorb reactive power if the voltage rises above its nominal value [4].

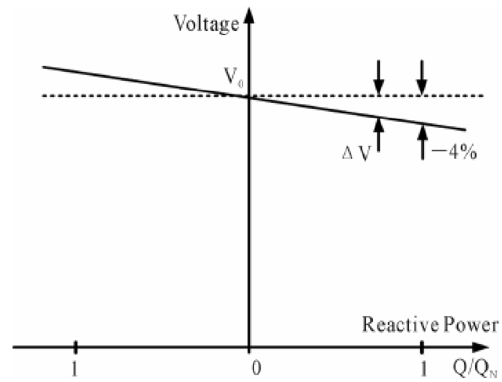

Fig. 3. Droop control of inverter terminal voltge.

Frequency and Active Power Control

The transition to islanded operation mode and the operation of the network in islanded mode require micro generation sources to particulate in active power-frequency control, so that the generation can match the load. During this transient period, the participation of the storage devices (flywheel) in system operation is very important, since the system has very low inertia, and some micro sources (micro turbine and fuel cell) have very slow response to the power generation increase. As already mentioned, the power necessary to provide appropriate load-following is obtained from storage devices (flywheel). Knowing the network characteristics, it is possible to define the maximum frequency droop as shown in Figure 4.To maintain the frequency between acceptable limits, the Vf inverter connected to flywheel will adjust the active power in the network. It will inject active power when frequency falls from the nominal value and will absorb active power if the frequency rises above its nominal value [4].

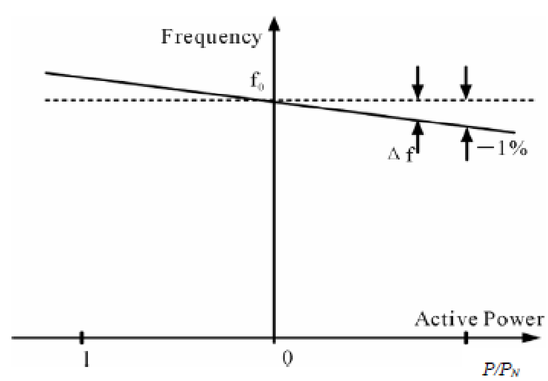

Fig. 4. Frequency droop control of Vf inverter.

Ramp Rate Limit Control

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It is anticipated that system operators will require ramp rate control of tie line power. This control will operate by adjusting the power output of Microgrid assets to compensate for the variable nature of Microgrid loads and generation. Two rate limits are specified for both increasing and decreasing power flow.

i. maximum ramp rate averaged over one minute,
ii. maximum ramp rate averaged over ten minutes .

POWER QUALITY

Different electric loads can be problematic for power quality in microgrids but also microgrid can offer more options for power quality management. Type of problems can be divided to either voltage level problems or harmonic problems. Devices emitting harmonics can be usually filtered to comply with power quality norms but more active approach might have to be taken if the load just draws too much current.

It determines the fitness of electrical power to consumer devices. Synchronization of the voltage frequency and phase allows electrical systems to function in their intended manner without significant loss of performance. The term is used to describe electric power that drives an electrical load and the load's ability to function properly. Without the proper power, not operate at all. There are many ways in which electric power can be of poor quality and many more causes of such poor quality power. When a fault occurs on the isolated MicroGrid, the MicroGrid's reduced short-circuit current capability has a significant impact.

When the MicroGrid is connected the grid sources could provide fault current that is orders of magnitude greater than load current. This high fault current is easily distinguished from load current and thus is conventionally used to detect faults on radial distribution systems. Fault currents for grid connected and islanded operation of micro grid are different. The short circuit power varies significantly. Faults also causes loss of sensitivity, over current, earth leakage, disconnection of generators, islanding, reducing reach of over current relays, single phase connections and loss of stability.

Depending upon location of faults with respect to distributed generators and existing protection equipment, problems like bidirectional power flow and change in voltage profile occurs. The power output of distributed generators like synchronous generators, induction generators and inverter interfaced protection units is unpredictable due to which whenever there is a fault, power output of these DG sources changes .Modification in fault current level, device discrimination, reduction in reach of impedance relays, reverse power flow, sympathetic tripping, islanding, single phase connection, selectivity are the key protection issues.

HARMONICS

The harmonic results due to the operation of power electronic converters. The harmonic voltage and current should be limited to the acceptable level at the point of wind turbine connection to the network. To ensure the harmonic voltage within limit, each source of harmonic current can allow only a limited contribution, as per the IEC-61400-36 guideline. The rapid switching gives large reduction in lower order harmonic current compared to the line commutated converter, but the output current will have high frequency current and can be easily filter-out [8][10].

STABILITY

For an AC power grid to remain stable, the frequency and phase of all power generation units must remain synchronous within narrow limits. A generator that drops 2 Hz below 60 Hz will rapidly build up enough heat in its bearings to destroy itself. So circuit breaker trips a generator out of the system when the frequency varies too much. But much smaller frequency changes can indicate instability in the grid [5].

PROTECTION SYSTEM AND INTEGRATION OF VARIOUS DISTRIBUTED GENERATOR

The major challenge in micro grid is the protection system. Protection system must respond to both main grid and micro grid faults. Protection system should isolate the micro grid from the main grid as fast as possible to protect the micro grid. When Distributed generators (DG) are integrated to form the micro grid it is essential to assure that the loads, lines and DG on island are protected. The fast operation of protection improves the ability to maintain synchronism after transition to islanded operation, which is crucial from viewpoint of stability. The various protection issues arises when the integration of DG is done with distribution level network, there is change in faults current level of network, possibility of sympathetic tripping, reduction in reach of distance relays, loss of relay coordination and unintentional islanding [6].Protection problem arises in island operation with inverter based sources as inverter based sources are limited by ratings of silicon devices. When micro grid is used to improve service continuity, distributed network protections are needed to be modified. Automatic and fast operative devices are used to detect faulty portion of network, which disconnects it rapidly and automatically it will also reconfigure the network depending upon requirement.

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4 FUTURE OF MICROGRIDS

Microgrids, a cutting-edge technology, feature intelligent control systems that enable self-coordinated operation. With their energy flexibility, cost-efficient scheduling, and optimized management capabilities, they act as controllable power supplies or loads in a power grid network, giving them enormous growth potential [7]. Although the technical immaturity, utility reluctance, and current cost structure of microgrids will limit their application to niche markets in the short term, the future for microgrids is promising. Perhaps the largest benefactors of microgrids will be foresighted utilities, communities, industrial parks and the like, that will leverage microgrids to optimize their energy costs with the added bonus of generating revenue opportunities by selling energy back to the grid during periods of peak demand.

5 CONCLUSION

This paper has discussed some power quality aspects in a standalone microgrid various protection issues that arise when microgrid is integrated to main grid. The future development on microgrid is done with the goal that microgrids will be able to make a valid, greener, contribution to the worlds growing future energy needs.

An islanded microgrid must have its own resources to maintain the power quality, mainly the voltage and frequency rated values. The voltage variations depend of the system reactive power, while the frequency depends of the system active power balance. The filter presents good dynamic and steady-state response and it can be a much better solution for power factor and current harmonics compensation than the conventional approach. Besides, the shunt active filter can also compensate for load current unbalances, eliminating the neutral wire current in the power lines [9].

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