International Journal of Electrical and Electronics Engineers
Vol. No.8 Issue 01, January-June 2016
www.arresearchpublication.com
IJEEE
ISSN 2321 - 2055

INTERCONNECTION OF MICROGRID WITH MAIN GRID

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ABSTRACT

Amicrogrid consists of microsources that could be conventional or renewable. The distribution network becomes active with the integration of Microgrid. The successful development of the microgrid concept implies the definition of a suitable regulation for its integration on distribution systems. The paper outlines the main achievements in these different areas, based on published results and projects outcomes. They result from tighter collaboration for microgrid interconnection to distribution network. So far, these achievements are at the research or demonstration level. However, one may witness that transfer from research to commercially available products has been particularly fast in the last few years, owing to intensification of collaboration between researchers, software developers and Microgrid users, but also to potential commercial interests. Therefore, it is expected that new methodologies appearing in the research world will soon be in the hand of Microgrid users.

Keywords; Microgrid, Distribution Network ,Point of Common Coupling

I. INTRODUCTION

The restructuring of electric power systems has changed thenature of power generation allowing smaller units to be distributed across the network and closer to the loads. Thesegenerators are referred to as Distributed Generators (DG). DGunits can be classified into two main categories based on theirnature: dispatchable generators (diesel generators, combinedheat and power generators, etc.), and non-dispatchablerenewable generators (wind, solar, etc.). The accommodationof distributed generators in the distribution networks is one ofthe most significant and challenging research topics in powerengineering. The electricity grid is being restructured to allowfor higher penetration levels of distributed generators in orderto maximize their utilization. Microgrids (MG) have beenrecently introduced in distribution networks and are defined assmall power systems that consist of various distributed microgenerators which are capable of supplying a significant portionof the local demand. Microgrids provide multiple benefits tothe system including reducing customers’ interruption costs,reducing system losses, and accommodating higher penetrationlevels of renewable resources [1], [2]. A typical microgridstructure is being shown in figure 1. Microgrids can operate ingrid-connected mode, in which they are allowed to exchangepower with the upstream grid, or in isolated mode, where they

are disconnected from the upstream grid and the localgenerators are the only source of power supply. An EnergyManagement System (EMS) is used in micrograms to optimizetheir operation, schedule local generation, and control all the interactions with the upstream grid .optimizing served, power losses, and gas emissions. In order to maximize the benefits of the resources available in the grids a micro grid, an optimal scheduling of the power generation isrequired. Generation scheduling problem is an optimizationproblem that consists of two sub-problems: Unit Commitment(UC), and Economic Dispatch (ED). The unit commitmentproblem provides the on/off status of the dispatch able generation units over a daily or weekly time horizon. On theother hand, the economic dispatch problem finds the optimaloutput power for the units committed by the unit commitmentproblem over shorter time horizons: i.e., hourly or in real time. Both problems search for an optimal solution that satisfies thegenerators' and network's constraints while meeting thedemand and the reserve requirement While in micro grids, generation capacities are in the range of tens of kilowatts tofew megawatts. This reduction in the size affects the operationparameters of the generators leading to more flexible andfrequent on/off switching actions [2].

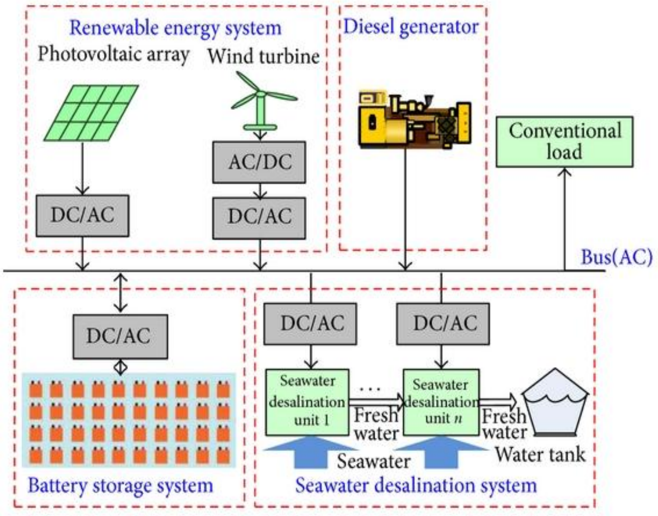

Figure 1: A typical microgrid structure [3]

One of the benefits of establishing microgrids is increasing the penetration of renewable resources in the grid. However, amajor problem with this kind of generators is their intermittent nature. The amount of power generated by renewable thermal generators. Furthermore, renewable generators can cause load mismatch and voltage instability in the system [3].

These problems are more significant in the case of microgridsdue to having a higher penetration level of renewable generatorscompared to large power systems . Uncertainties associated with renewable generators must be taken into consideration when scheduling the power generation in microgrids in order to achieve reliable solutions. Hence, reformulating the scheduling problem and developing new models is a necessity to produce efficient and robust commitment schedules.

Microgrids can operate under two different modes of operation. The major difference between the two modes is the sources ofpower generation that can be used to supply the demand and thereserve requirement. This has a direct impact on the generationscheduling problem making it more challenging. Therefore, theformulation must be updated to account for the objectives andconstraints of each mode of operation. Doing so will result in abetter distribution of the available generation capacities in the microgrid and will allocate the required amountof spinning reserve to maintain the system's stability and tomitigate the effects of uncertainties [4].

Developing more accurate and reliable scheduling models thataccount for the effects of uncertainties and modes of operationis the main motivation behind this research. The workpresented in this paper will examine the impacts of these added difficulties on microgrid interconnection to distribution system.

II. MICROGRID INTERCONNECTION ISSUES

Electricity grids must have standard conditions of supply toensure that end-use equipment and infrastructure can operatesafely and effectively. These conditions are commonly referredto as power quality requirements and are defined in standards or by supply author ities . They most commonly relate to voltage and frequency regulation, power factorcorrection and harmonics. In all distribution networks,challenges to maintaining these power quality requirementsarise from the technical characteristics and end-user operation ofelectrical loads, and the network equipment and lines. Someloads have significant power demands that increase networkcurrent flows pulling down line voltage (such as electric hotwater heaters and large air-conditioners). Some have veryshort-lived but major power draws on start-up (such as standardinduction motors) driving voltage fluctuations. Some havesignificant reactive power needs (again including motors) or

create significant harmonics (such as computer powersupplies and fluorescent lighting). Power quality at different points of the distribution network at any time is impactedby the aggregate impacts of loads and network equipment inhighly complex ways.

Microgrid connected to the distribution network cansignificantly influence these aggregated impacts. Someimpacts can be positive: for example where PV generation isclosely correlated to air- conditioning loads and hence reducesthe peak network currents seen in the network. At other timesDG can have adverse impacts – for example where maximum PV generation occurs at times of minimum load hence reducing current flows below what they wouldotherwise be, and causing voltage rise in the network. Other issues related to the connection of DG to a network that are not is generally also seen with loads include possible unintentional islanding,1 fault currents, grounding and highly correlated power output fluctuations, all issues that can have significant impacts on power quality yet also system safety, security and control. The following discusses these issues as they relate to DG, as well as options for addressing them. We consider options ranging from those currently being used through to those undergoing trials or still in the R&D stage.

(a) Voltage fluctuation and regulation: Voltage fluctuation is a change or swing in voltage, and can be problematic if it moves outside specified values. Microgridsystems are relevant to voltage regulation because they are not only affected by voltage fluctuations that occur on the grid,but can cause voltage fluctuations themselves—where the latter effects can be divided into voltage imbalance, voltage rise leading to reverse power flow, and power outputfluctuations. These are as: Grid-derived voltage fluctuations,Voltage imbalance, Voltage rise and reverse power flow,Power output fluctuation.

In many locations and networks, installation of relatively large PV systems does not result in significant voltage rise orreverse power flow issues, but where voltage rise is anssue, four common approaches currently used tominimise voltage rise and applied to the PV systemsthemselves [3] are:

□ □ Ensure the PV systems are smaller than the minimumdaytime load at the customer metre, so the site should neverexport power to the grid.

□ □A minimum import relay (MIR) can be used todisconnect the PV system if the load drops below a presetvalue.

□ □ A dynamically controlled inverter (DCI) can beused to gradually reduce PV output if the load dropsbelow a preset value.

□ □ A reverse power relay (RPR) can be used todisconnect the PV system if the load drops to zero orreverses direction.

A DCI set to maximise PV output while avoidingexport would allow greatest use of the PV system.However, all these measures not only limit voltage rise but alsorestrict the potential penetration of PV systems, limiting theircontribution to sustainable energy production. Alternativesto these revolve around changes to the network or customerloads, and while they are not currently used, they could beimplemented with appropriate policy settings. For example:

□ □Require customer loads to operate at improved powerfactor, again reducing the need for high upstream voltage.

□ Require customers with large loads (who create theneed for the high upstream voltage), to incorporate someform of load- shedding scheme. Shedding of non-criticalloads could be triggered when network voltage goes below aspecified thresh- old (which occurs at times of high load),again reducing the need for high upstream voltage.

□ □Discretionary load scan be used at times ofhigh network voltage (which occurs at times of lowload), to soak up the extra power provided by PV.

□ □Storage can also be used to soak up theextra power provided by PV.

(b) Power factor correction: Poor power factor on thegrid increases line losses and makes voltage regulationmore difficult. Inverters configured to be voltage-followingare generally set to have unity power factor,5 whileinverters in voltage-regulating mode provide current that isout of phase with the grid voltage and so provide powerfactor correction. A number of factors need to be taken intoconsideration when using inverters to provide power factor correction. The first is that to provide reactive power injection while supplying maximum activepower, the inverter size must be increased. The secondfactor to be taken into consideration is that the provisionof reactive power support comes at an energy cost. The third factor is that simple reactive power support canprobably be provided more cost-effectively by SVCs orSTATCOMS, unless of course the inverter is to beregardless as part of a DG system. Their energyloss is also considerably less than for the equivalent inverterVAr compensation. The main advantage of inverter VArcompensation is that it is infinitely variable and very fastin response to changes in the power system. Thefourth factor is that while this sort of reactive powercompensation is effective for voltage control on mostnetworks, in fringe of grid locations system impedancesseen at the point of connection are considerably moreresistive, and so VAr compensation is less effective forvoltage control. In these situations, real power injection ismore effective for voltage regulation.

In summary, PV inverters are capable of VAr compensation to assist with voltage control on the grid,although this requires larger inverters and comes at an energy cost. How the VAr compensation is valued andwho pays for the energy has generally not beenaddressed. Although large load transients may justify aninverter, SVCs or STATCOMS may be a more cost effective source of VAr compensation. Of course,where an inverter is already paid for as part of a separateDG system, it is likely to be the more cost-effective option.

(c) Frequency variation and regulation: Frequency isone of the more important factors in power quality.The frequency is controlled by maintaining a balancebetween the connected loads and generation. It is controlled within a small deviation: for example ,in Japan thestandard is 0.2–0.3 Hz; in the U.S. it is 0.018–0.0228 Hz;and in the European UCTE it is 0.04–0.06 Hz [7].

Disruptions in the balance between supply and demand leadto frequency fluctuation, it falls when demand exceeds supplyand rises when supply exceeds demand [7]. Power systemscontain a number of sources of inertia (e.g. large rotatinggenerators and motors), which result in considerable timeconstants involved in frequency movements when there is amismatch between load and generation. The time constantsdepend of course on the size of the system and how well it is interconnected. With the increasing penetration of intermittent energy sources such as wind and solar, frequencycontrol becomes more difficult. Although the contribution topower fluctuation from PV systems is currently much smallerthan that from wind generators, as the number of grid-connected PV systems increases, the issue of frequency fluctuation may become more noticeable.

(d) Harmonics: Harmonics are currents or voltages with frequencies that are integer multiples of thefundamental power frequency. The standard frequencys 50 or 60 Hz depending on the country, and so aharmonic in a 50 Hz country could be 100, 150, 200Hz, etc. Electrical appliances and generators all produceharmonics and are regulated under the International Electro technical Com- mission (IEC) ElectromagneticInterference (EMI) standards. However in large volumes(e.g. computers and compact fluorescent lamps), theseharmonics can add up to cause interference that can resultin vibration of elevators, flickering of TV monitors andfluorescent lamps, degradation of sound quality, malfunctioningof control devices and even fires.

Even when a voltage source inverter is used to help correctpoor harmonic voltage, and so the inverter producesharmonic currents to assist in correcting the grid voltage, itsenergy output is reduced. This is equitable provided theowner of the inverter is also the cause of the harmonics onthe grid and so they are assisting with correction of theirown problem. However the owner of the inverter may beexperiencing high harmonic flows, and so reduced energyoutput, because of the poor harmonic performance of othercustomers on the power system. This is another reason why current source inverters are common their output is notgenerally affected by the grid's voltage harmonics.

Harmonics can also be eliminated using passive andactive filters, which are generally cheaper than inverters.Passive filters are composed of passive elements such ascapacitors or reactors, and absorb harmonic current byproviding a low-impedance shunt for specific frequency domains. They come in two forms: tuned filters (which aretargeted to eliminate specific lower-order harmonics) andhigher-order filters (that can absorb entire ranges ofhigher- order harmonics). Active filters detect harmoniccurrent and generate harmonics with the opposite polarity forcompensation. They are better than passive filters because they can eliminate several harmonic currents atthe same time, they are smaller and quieter, and they donot require a system setting change even when a changeoccurs in the grid.

In summary, while the most common type of inverters(current- source) do not create harmonic distortion, they alsodo not provide the harmonic support required from the grid.Voltage-source inverters can provide harmonic support butdo so at an energy cost and there are a variety of harmoniccompensators that are likely to be cheaper. Labelling thatidentified the type of inverter (voltage or current source)would help purchase of voltage source or current sourceinverters as required, as would financial compensation forreducing energy losses if voltage source inverters areinstalled. Note that, unless specially configured, PV invertersdisconnect from the grid when there is insufficient sunlightto cover the switching losses, meaning that no harmonicsupport would be provided outside daylight hours. Ofcourse, requiring loads to not create excessive harmonics orTHD in the first place could have a significant andbeneficial effect.

(e) Unintentional islanding: Unintentional islandingoccurs when distributed generation delivers power to thenetwork even after circuit breakers have disconnected thatpart of the network from the main grid and associated generators. This ca ncause a number of differentproblems [6, 8, 10, 12, 14, 15]:

□ □ Safety issues for technicians who work on the lines,as well as for the general public who may be exposed toenergised conductors.

- It may maintain the fault conditions that originallytripped the circuit breaker, extending the time that customersare disconnected.
- possible damage to equipment connected to the island because of poor power quality (e.g. Whereinverters are in voltage-following mode).
- Transient overvoltages caused by ferroresonance andground fault conditions are more likely when an unintentional island forms.
- Inverters could be damaged if the network isreconnected while an island of DG exists.
- It is possible for a network that does not havesynchronizing capabilities to reclose in an out of phasecondition, which can damage switchgear, power generation equipment and customer load. Since islanding is a well-known problem, grid inverter technologyhas developed to include anti-islanding features asare required by local regulations and standards. Islandingdetection methods can be divided into five categories: passive inverter- resident methods, active inverter-residentmethods, passive methods not resident in the inverter, activemethods not resident in the inverter, and the use ofcommunications between the utility and DG inverter [15].

- Passive inverter-resident methods involve the detection ofthe voltage or frequency at the point of grid connectionbeing over or under specified limits. These methods alsoprotect end-users’ equipment.
- Active inverter-resident methods involve active attempts tomove the voltage or frequency outside specified limits—which should only be possible if the grid is not live.
- Passive methods not resident in the inverter involve the useof utility-grade protection hardware for over/under frequencyand over/under voltage protection.
- Active methods not resident in the inverter alsoactively attempt to create an abnormal voltage or frequencyor perturb the active or reactive power, but the action istaken on the utility side of the inverter connection point.
- Communications between the utility and DG inverter methodsinvolve a transmission of data between the inverter or system and utility systems, and the data is used by the microgrid system to determine when to cease or continueoperation.

In summary, passive, active and communications-basedislanding detection methods have a number of issues thatneed to be resolved. It is likely that different mixes of thesemethods will be required in different locations, and thatphasing out or replacing less effective methods will not be asimple task, and will likely involve a coordinated approachby government, utilities and installers and owners of DGsystems.

(f) Other issues: Other issues, that are likely to be ofless importance and for space reasons have not beenincluded here, include fault currents and effective grounding, DC injection and high frequency waves and of course the impacts of aggregated Microgrid on sub-transmission and transmission networks.

III. FACTORS THAT INFLUENCE HOW THESE ISSUES ARE ADDRESSED

As discussed in the previous section, there are many potential technical issues associated with connection of Microgrid to electricity networks, especially at highpenetrations. While some of these impacts may becurrent flows, some adverseimpacts are likely at significant penetrations whilst others may also be possible in low penetration contexts. The challenge is to facilitate the deployment of DG in ways that maximisestheir positive grid impacts whilst minimising adverse impacts, within the context of wider societal objectives associatedwith DG uptake. The types of technical solutions likelyto be required to achieve this may sometimes be different indifferent countries, simply because they have differenttypes of electricity networks, renewable energy resources,mixtures of conventional and renewable energy generators,correlations between renewable generation and load,government priorities and, ultimately, technical capacitieswithin utilities, government and the private sector. Microgrid of course does not represent the first disruptiveseto f technologies for electricity industry arrangements. Forexample, wind energy represents the first major highly variableand somewhat unpredictable generation to achieve high penetrations in some electricity industries. As such, it hastested, and in some cases driven changes to, current technicaland wider industry arrangements. Recent high financialsupport for PV, such as Feed-in-Tariffs in Europe and grantbasedsupport in Australia have led to very rapid increases ininstalled PV capacity, with institutional and electricity sectorcapacity falling behind in some cases. Problems have been exacerbated when such financial support has been linked totime or capacity-based caps, which have encouraged a rush toinstall. Poor quality components and installations have often resulted, which will cause problems for the Microgridsector in future.

Thus, addressing these technical problems requires morethan just the technical solutions described above. It willrequire policy and regulatory frameworks to coordinate thedevelopment and deployment of the different technologies in ways most appropriate for particular jurisdictions.These frameworks will be different for different countries, and so no single approach will be appropriateworldwide. Thus, this section discusses the non-technicalfactors that influence which types of technological solutionsare most likely to be appropriate, and provides suggestionsfor increasing the likelihood of best practise. These issues arehandled by; government, regulator and electricity utilitiesitself, using Institutional and regulatory barriers, restructuring.Existing electricity infrastructure, incorporating more research.

IV. CONCLUSION

The paper gives an overview of recent advances and of thechallenges left for the short to medium-term for Microgrid Interconnection .The successfuldevelopment of the microgridconcept implies the definition ofa suitable regulation for its integration on distribution systems.In order to define such a regulation, the identification of costs and benefits that microgrids may bring is a crucialtask. Actually, this is the basis for a discussion about the wayglobal costs could be divided among the different agents thatbenefit from the development of microgrids. Among otheraspects, the effect of microgrids on the reliability of thedistribution network has been pointed out as an importantadvantage, due to the ability of isolated operation inemergency situations. This paper gives the overview of such type issues in microgrid interconnection to distribution network.

So far, these achievements are at the research or demonstration level. However, one may witness that transfer from research tocommercially available products has been particularly fast inthe last few years, owing to intensification of collaborationbetween researchers, software developers and Microgrid usersbut also to potential commercial interests. Therefore, it isexpected that new methodologies appearing in theresearch world will soon be in the hand of Microgrid users.

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