# Sustainability and Resilience of Microgrid in Rural Environment

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***Abstract:*** The radial distribution system, which are in operation from past decade are passive, they are now upgraded by SCADA and other automation techniques. In present era focus on Distributed Generation (DG) based Microgrid were getting popular as it introduce a subgrid network for contingency when running in interconnected mode. Both utility and end user were conscious about sustainability and resilience of power flow in distribution network. In Microgrid hybrid AC/DC system enhances the system resilience and efficiency by utility of bidirectional interlinking converter (BIC). BIC manages to control subgrid parameters by decentralized controller; mainly by AC droop control Strategy. In this paper microgrid infrastructure along with its sustainability and resilience issues were taken into consideration.

***Index Terms:*** Distributed Generation (DG), bidirectional interlinking converter (BIC), Resilience, Droop Control, Decentralized Control

## I. INTRODUCTION:

Reliable utility grid is the need of modern power system with secure operation. As rural electrification and remote village power connectivity is to be resolved, distributed generation (DG) integrated with utility grid in-cooperating bidirectional interlinking converter (BIC). Due to restructuring of power system in present era, new topology and reforms of distribution network were introduced, with major development in DG integrated Microgrid, which are more robust and efficient than existing topology. With DG intact microgrid flexibility of distribution network grid increases for the supply of power and adjust power demand as per end users this enhances the reliability pertaining to more robust resilience capability. Resilience means the capability of system to predict and act with change in system to manage contingency situations'. BIC architecture is shown in figure 1, this contain both AC/DC system which represents the flexibility of microgrid system in terms of power flow, generation type and controllability. As DC system is not prone to dynamic problem of power flow and frequency variation along with system droop effects as in AC, due to this reason, former one is getting more popular in microgrid architecture thus utility of BIC get popularized.

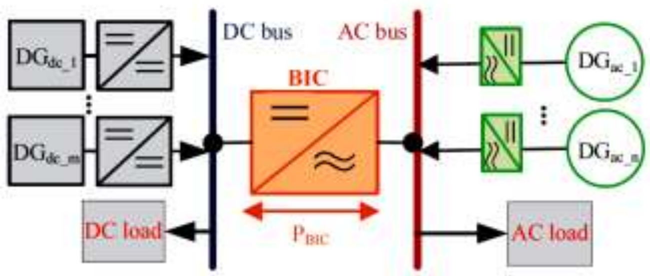



Figure 1: AC/DC Microgrid

As restructuring of power system were going on, an emerging localized integration of DG along with integrated power pool and distributed network is termed as "microgrid". Microgrid are more robust to dynamics of power system, and more controllable then large power system thus by the increased use of microgrid; resilience of system improves. Due to goal of renewable energy generation improvement, penetration of micro-turbines, wind power, Photovoltaic (PV) as distributed energy resources (DERs) going to increase and due to this subgrids and integration for microgrid network to improve resilience and efficiency [5]. Microgrids can [2]-[4]

a) Increase distribution network utilization capability,
b) Utilize Distributed Energy Resources (DERs), e.g. wind, PV and micro-hydro.
c) Will enable faster restoration measures.
d) Improves the efficiency by enhanced controllability and power flow flexibility.

Microgrid control strategies were taken from Kythnos microgrid, which is single phase islanded system with hybrid system of PV and diesel Generator [7].

The research focus on microgrid infrastructure modeling along with inherent capability for sustainability and resilience. This new topology which is evolving consist of both static system design and dynamic system during simulation. Power system components included in modeling are as follows:

1. Distribution Network
2. Distributed Energy Resources
3. Energy Storages
4. Central Controllers
5. Converters
6. Load Controllers
7. Local Load

Distribution network provide test bed for existing systems, on the basis of which new layout which is more sustainable and dynamic in operation were designed. With the introduction of microgrid and its subgrids in the distribution network, capability of system to serve critical load during and after catastrophic event adds to resilience capability of system. System resilience is also improved with channelized power flow utilizing feedback signals to ensure continuous and stable supply of electricity. Active and Reactive power flow in system is adjusted by converter dynamic capability for which BIC is being designed. BIC converter is capable to route power in both direction and this capability improves the system reliability.

## II. Modeling of Networked System

### *A. Static system design*

#### 1) Load forecasting

As the existing networked distribution grid termed as test system, due to continuous monitoring of power and load forecast prediction from past 15-20 Year records of consumer energy consumption were logged by utility. End users are residential loads, commercial and industry loads on the priority of load continuity of electric supply by distribution network and its subgrid architecture need to be designed. Thus forecasting errors will lead to sever problem in maintaining the continuous power demands and thus economic penalties to be beard [8].

#### 2) Optimal planning

Microgrid are subsection of integrated network, there are many contingency which were to be handled by BIC converter. Optimal planning of microgrid depends on the minimal net present cost (NPC) and cost of electricity (COE) for design analysis. Soft Computing techniques used to design and develop the software [9] for planning of microgrid architecture. Optimal changes in existing utility system with upgradation is designed using optimal load flow and optimal design techniques along with new topology knowledge. Optimization flow chart in figure 3, shows the design and development methodology while planning new system, as once system developed will have to exist for at-least 30-40 years, so each parameters to be taken in consideration.


Figure 2: Microgrid Contingency Scale

#### 3) Water availability

Water is one of the fuel of renewable energy power generation mainly in micro-turbine, fuel cells, biogassifier for DERs. Water is used as coolant and supplementary element of utility in many process, so availability of water in designing and development of systems. In those part of country where irrigation through canals were possible micro-hydro power plants integration to rural grid along with PV-plants will increase reliability of power flow. As the rural electrification were focused, microgrid operation in islanded modes and isolated distribution network were commissioned where integrated system does not found economical.

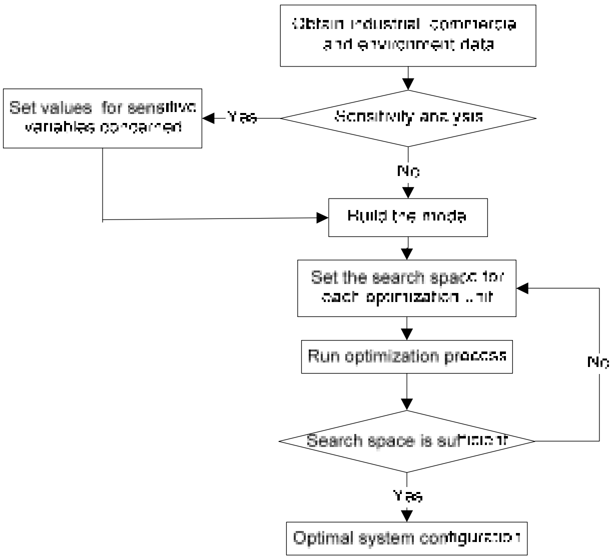



Figure 3. Optimization flow

#### 4) System reconfiguration

The load forecast and system optimization parameters will suggest reconfiguration architecture of existing utility grid. To get unknown random value of electric power system Monte Carlo method is used. Load flow analysis is done to understand the future extension capability, existing system node points for reconfiguration. Thus load flow will suggest better extension plan in integration with DG and involvement of microgrid and subgrid network maintaining resilience capability of system unaltered. In BIC integration of both AC/DC occurs as power generation source like PV generation produce DC and intact with local microgrid via subgrid network, along with it diesel generator system for contingency or system supply are also synchronized as shown in figure 1. Configuration of BIC controller is shown in figure 4; where $N_f$ and $N_V$ are normalized voltage and frequency. As BIC is interlinking point is capable of regulating Bus voltage, from Eq. 1 & 2 we get $N_f$ and $N_V$.

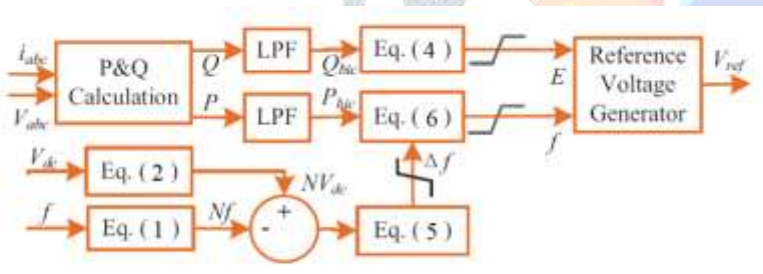



Figure 4: BIC control Block Diagram

$$Nf = \frac{f - (f_{max} + f_{min})/2}{(f_{max} - f_{min})/2} = 1 - \frac{a_c e_i(P_i)}{(f_{max} - f_{min})/2} \quad \text{.........(1)}$$

$$NV = \frac{V_{dc} - (V_{dc}^{max} + V_{dc}^{min})/2}{(V_{dc}^{max} - V_{dc}^{min})/2} = 1 - \frac{d_c e_i(P_i)}{(V_{dc}^{max} - V_{dc}^{min})/2} \quad \text{.........(2)}$$

$$f = f^* - aP_{bic}, a = \frac{f_{max} - f_{min}}{2 * P_{max}} \quad \text{.........(3)}$$

$$E = E^* - bQ_{bic}, b = \frac{E_{max} - E_{min}}{2 * Q_{max}} \quad \text{.........(4)}$$

$$\Delta f = (NV - Nf) * G_f \quad \text{.........(5)}$$

$$f = f^* - aP_{bic} + \Delta f \quad \text{.........(6)}$$

Instead of using the stable configuration system, faulty operation DG intact microgrid to be simulated which analysis the settling time and risk analysis. Once the main source voltage fails then the DG system should supply AC/DC power flow in the system, this analyse the converter dynamics and control system scheme capability. Figure 6 shows grid connected microgrid with control unit, it is modeled in PSCAD-EMTDC.

### *B. Dynamic system simulation*

#### 1) Systems integration

In this paper figure 1 shows the BIC configuration on the basis of this PSCAD model is developed for modeling in which DERs, converters, and subsystem is designed for resilience analysis. Droop characteristic of DGs along with integrated grid are shown in figure 5 (a) and (b), are power cushion of droop shift factor is shown. Controlling of this system for integrated grid connected and islanded mode is to be tested. In the characteristic $P'_{bic}$ of positive side represents active power flow while $P_{bic}$ represents flow of power in negative directions. The droop characteristics' of AC Bus between two subgrids is inherently supported by $P'_{bic}$, from Eq. 3 and 4 system droop characteristics can be adjusted.


(a) (b)

Figure 5: (a) Shifting Capability of BIC frequency power droop characteristic (b) Frequency Droop Characteristic

#### 2) System control methods investigation

In this resilience analysis for the system during and after catastrophic event is simulated in model as shown in figure 6. It comprises of three phase voltage source converter (VSC), DG, series filter, transformer and parallel RLC load, controller integrated to the grid. With the analysis of system resilience behavior new control strategies and controlling methods were under development for transition between grids connected and islanded operation.

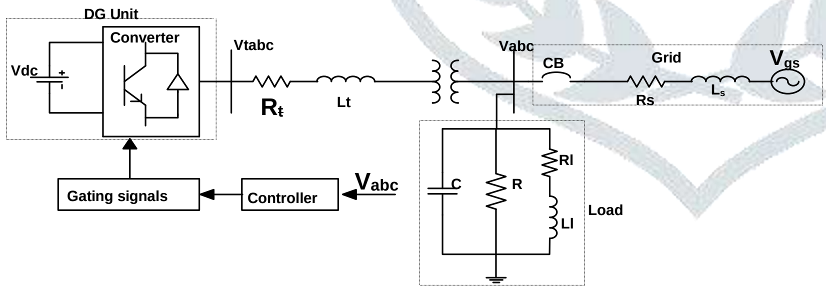
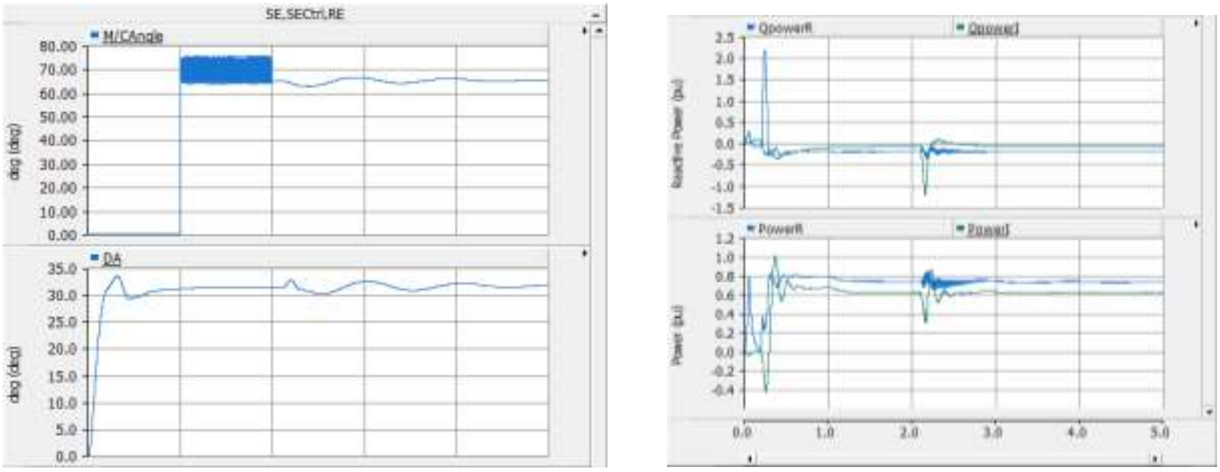



Figure 6. Grid-connected microgrid with control circuit

This part is extension of work done in [10], Converter output is shown in figure 7. In this modeling of system is done using PSCAD-EMTDC, effect of system resilience which is behavior of system before and after the transient condition were analysed in this paper. In figure 7 (b) active and reactive power variation of the system is shown, where we understand the fact that with transition control over both power is required for stable operation so that resilience capability of system should be improved.




(a) (b)

Figure 7. (a) and (b) Simulation Result

## III. CONCLUSION

In this research rural distribution grid and its integration issues with new developing microgrid for improvement of resilience of new architecture were studied. This research article introduce sustainability and resilience of microgrid in rural environment. BIC is taken as the reference interconnector of subgrids for microgrid integration. In this Droop characteristic of DGs were also evaluated, which help to design and develop controller for having sustainable supply in catastrophic phase, thus resilience of new system improved by inheriting this capability in it. BIC controller and DREs integrated system is represented in this paper, research for the resilience improvement is carried on after this study to empower controller, for the catastrophic conditions. As the system taken for rural environment study with elementary changes, research will be continued with large integrated power systems and different level of test.

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