Various Control Strategies for Hybrid Microgrid : a Review

Bhavesh Raval and Rital Gajjar

May 2, 2022

Various Control Strategies For Hybrid Microgrid : A Review

Bhavesh C. Raval[1,2, b)] and Dr. RitalR. Gajjar[3, b)]

[1]*Department of Electrical Engineering, C.U.Shah College of Engineering & Technology,C.U.Shah University, Wadhwan city, 363020, Gujarat, India*
[2]*Ph D scholar, Electrical Engineering, Faculty of Engineering and Technology, Parul University,P.O.-Limda, Ta. Vaghodiya,391760, Dist. Vadodara*
[3]*Department of Electrical Engineering, Parul Institute of Technology, Faculty of Engineering and Technology, Parul University, P.O.-Limbda, Ta Vaghodiya, 391760, Dist. Vadodara.*

[a)] *Corresponding author: bhavesh.eee.ccet@gmail.com*
[b)]*rital.gajjar@paruluniversity.ac.in*

Abstract. This paper reviews the research work on control strategies carried out for hybrid micro grid in the span of the years between 2018-2021.The various challenges found by the researches are also listed. It provides the macroscopic understanding on the research activities of recent past and enables the reader to get acquainted with recent trends.

INTRODUCTION

Due to the advancement in PV cell technology, Wind power technology the power generation and distribution using a local micro grid is proving economical. For the stability and reliability as well as bidirectional power flow and operation it is advantageous to combine the ac grid with the existing d.c. micro grid. This results in to great saving in economical aspect and alleviates the transmission operations. However, it also possesses the challenges of controlling and stabilization of suchformation addressed as hybrid micro grid. It is also the topic of interest for researchers in the concerned area. This paper reviews the various control strategies implemented by various researchers in the recent year from 2018-2021 to control the hybrid micro grid operation and issuesstill need to be addressed for better operation and control strategy.

VARIOUS TOPOLOGY FOR HYBRID MICROGRID

The hybrid micro grid consists of combination of many of the below listed components which includes: (1) PV Cell array (2) Maximum Power Point Tracker (3) Charge Controllers (4) Wind Turbine (5) Doubly Fed Induction Generator (6) Battery Storage System consisting of Lithium Iron, Lead acid and other rechargeable batteries (7) Diesel Generator Set (8) Voltage Source Converter working as an interlink between AC and D.C. Grids (9) Conventional A.C. distribution grid. (10) Sensors for various purpose (11) Conventional D.C. loads. (12) Controllers for converters (15) Super Capacitors

As per the advancement in Technology and liberalization of government policy, the electric vehicles such as scooters, car and buses will be included in the load part, the fuel cell shall be part of power generation and super conducting coil may be the part of energy storage system. The schematic for the same is shown in figure 1.

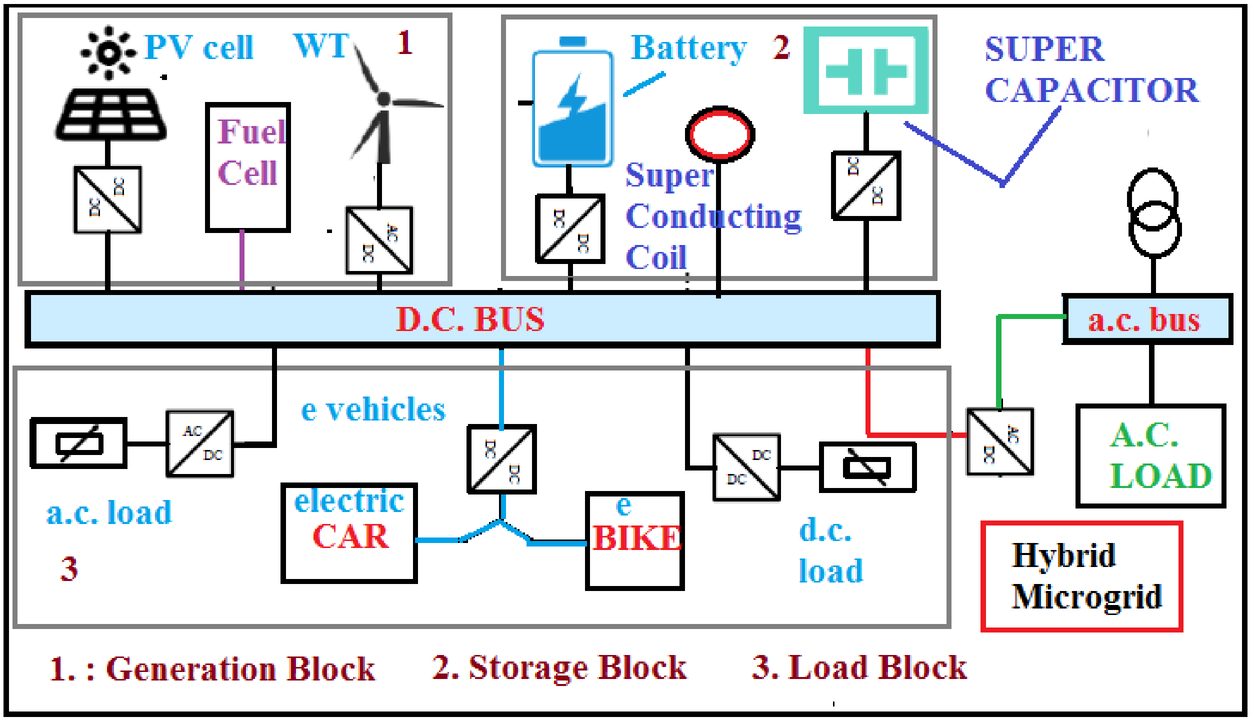

Figure 1. Various Topology for Hybrid Micro grid

PARAMETER MONITORING

The following parameters are monitored for hybrid grid operation : (1) Active power (2) Reactive power(3)Load frequency (4) Load Voltage (5) D.C. Bus Voltage (6) Output current of converter (7) Output current of battery (8) Output current of super capacitor (9) Wind turbine speed (10) Status of Charge (SOC).

CONTROL STRETEGIES

The various control strategies conceived and implemented by various authors either by simulation and/or by experimental results are listed and described below:

1. Decentralized Current Splitting Strategy [1]:

This method focuses on battery and super capacitor components of hybrid system in DC micro grid.The filter designed in first order mode governs the function in frequency domain and slop of the voltage to frequency curve is regulated in unique manner.The power fulfillment in steady state is looked after by battery. The super capacitor aims on meeting the challenges of transient perturbance

This method is designed by amalgamation of filter design and loop regulation strategy. For the fulfillment of transient power management demand, the battery resistance Rb and super capacitor resistance Rc are represented as frequency domain functions. This virtual change is utilized for transient power management operation initiated by super capacitor. For the management of excess load current, the battery focus on the low frequency component which is obtained by filtering action of low pass strategy while high frequency part is allotted to super capacitor. The summary of various equations utilized for the implementation of the strategy is listed by figure 2.

$v_{bus}(s) = V_{ref} - R_i i_i(s)$ (1) $i_j(s) = \dfrac{V_{ref} - v_{bus}(s)}{R_i}$ (2)	$\begin{cases} i_o(s) = i_g(s) - i_{load}(s) \\ i_{oB}(s) + i_{oSC}(s) = i_o(s) \end{cases}$ (5)
$\begin{cases} Z_B(s) = R_B F_B(s) \\ Z_{SC}(s) = R_{SC} F_{SC}(s) \end{cases}$ (3)	$\begin{cases} i_{oB}(s) = \dfrac{Z_{SC}(s)}{Z_B(s) + Z_{SC}(s)} i_o(s) \\ i_{oSC}(s) = \dfrac{Z_B(s)}{Z_B(s) + Z_{SC}(s)} i_o(s) \end{cases}$ (6)
$\begin{cases} i_{oB}(s) = \dfrac{V_{ref} - v_{bus}(s)}{Z_B(s)} \\ i_{oSC}(s) = \dfrac{V_{ref} - v_{bus}(s)}{Z_{SC}(s)} \end{cases}$ (4)	$\begin{cases} i_{oB}(s) = G_{LPF}(s) i_o(s) \\ i_{oSC}(s) = (1 - G_{LPF}(s)) i_o(s) \end{cases}$ (7) $\begin{cases} F_B(s) = 1 - G_{LPF}(s) \\ F_{SC}(s) = G_{LPF}(s) \end{cases}$ (8)

Figure 2. Summary of various equations used for Decentralized Current Splitting Strategy.

2.Anti Windup PI Control Strategy [2]:

This control scheme addresses the issue for a system containing wind turbines driven generators. diesel engine driven generator, sets of battery along with a dumping load. When PI controller is used without taking into account of saturation phenomena the method is having a tendency of rise in integral error even though the saturation in input has been observed.On significant reduction in error, the increase in integral quantity bans the prompt resumption of normal operation from controller that results in elongation of response time.Such drawback is recognized as integral windup phenomena while dealing with PI controller. The elimination is carried out by ceasing the integration by sensing that the input signal saturation has occurred.While it is necessary that reduction in integral flaw is primary action it results in the slow down of output characteristics. The solution for the same aims of ceasing the integral of error once the saturation is observed for feed in signal. The strategy mention here aims in for regulation of voltage as well as frequency in active power domain using anti-windup method. This action lessens the phenomena of overshoot and also reduces the settling time while the parity is matched with that of stand-alone Positional Integral Controller.The concept of AWPI control action focus on the dump load regulation on equal aspect.

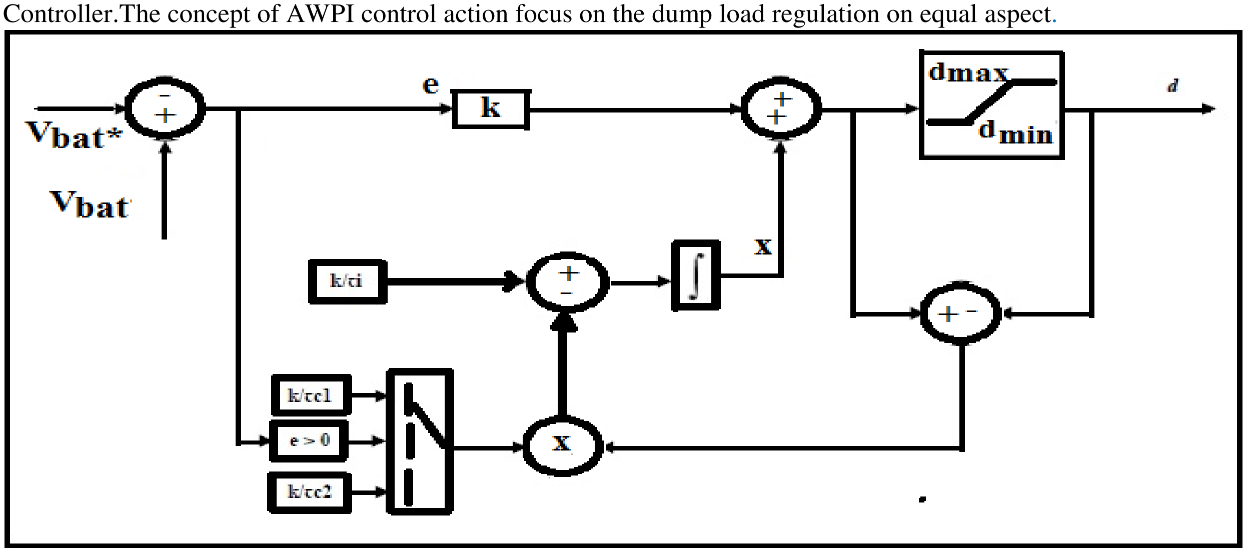

Figure 3. Model of Anti Windup PI Controller [2]

3. A Power Control Strategy [3]:

This strategy utilize the data received from the Micro Grid Control Centre and aims to improve the power reliability and stabilization of the power system in the event of power failure. MATLAB Simulink is used to create the experiment model.Simultaneous presence of conventional and renewable energy source creates the controlling challenges in voltage of the central grid as well as frequency regulations. Hence the synchronous generator is introduced as an a.c. source element in micro grid and supplies the power during blackout and stabilize the frequency. The variation in frequency is reviewed in both the conditions when Battery Energy Storage System (BESS) is present and absent. Micro Grid Control Centre (MGCC) plays critical role for the stability of the system. By collection and comparison of various data received from the sensors it selects the best working mode. The control of Battery Storage System (BSS) in presence of Wind Diesel Hybrid System (WDHS) is achieved through Distributed Control System (DCS).

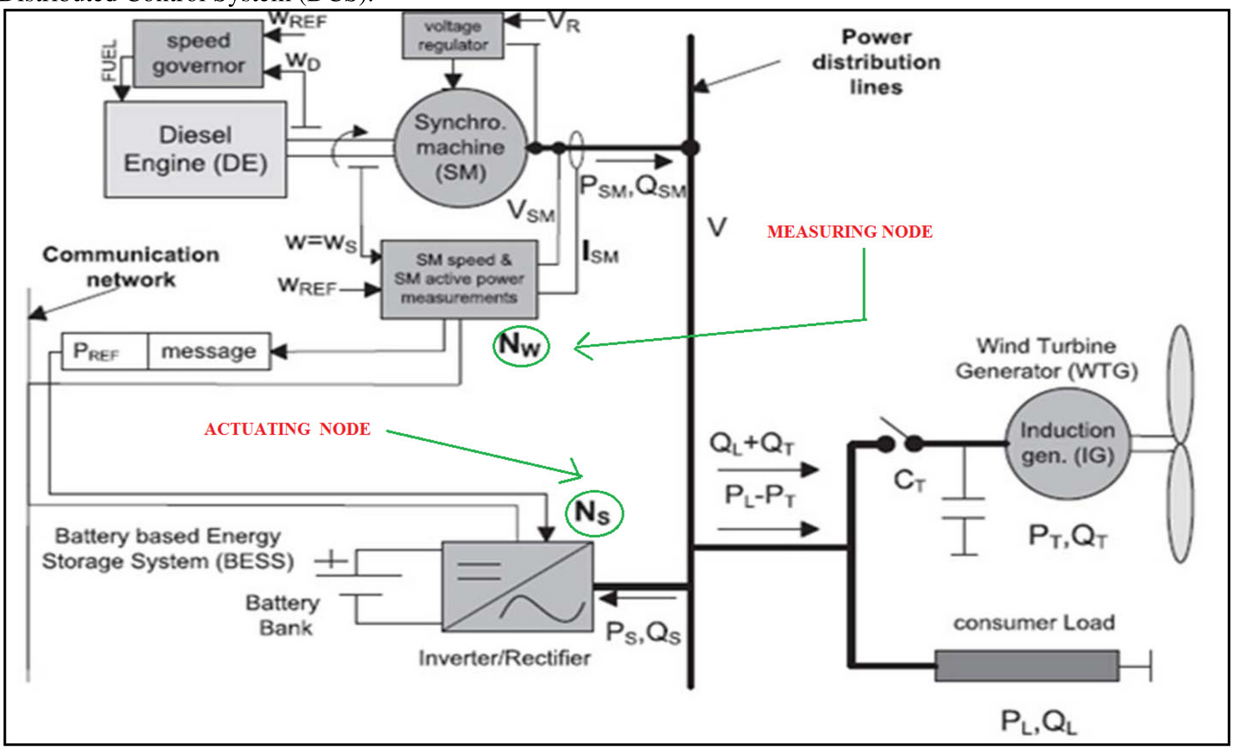

Figure 4. Measuring Node and Controlling Node in Power Sharing Control Strategy for Distributed Generator Output

In the DCS several physically distributed CPU based control units are linked through communication network. The sensor node of DCS measures shaft speed and active power of synchronous generator while actuating node is connected with converter. Depending upon the measurement and status of operation mode from WDHS, The power to be received or fed by the battery set for obtaining the balance in real power is evaluated by control centre of micro grid.The sensor and actuator mode are shown in figure4 while energy management algorithm is shown in figure 5.

4.Link Up Of Many Hybrid Micro Grids By Novel Droop Regulated Converter [4]:

The scheme is represented in Figure 6. This strategy addresses the control and operation of multiple hybrid micro grid. The design is self-governingand eliminates the necessity of multiple converter operation in parallel mode.The measurements are focused for d.c. bus voltage. The converter power and frequency readings are also monitored to decide the scale factors.These scaling factors are given to PI controller. Based on this, the design of droop based controller is modified. When load changes occur in ac grid, its frequency changes and Inter Link Converter (ILC) manage the power flow within the converter. The power directions in converter are function of load change that is reflected by change in bus voltage at d.c. side.

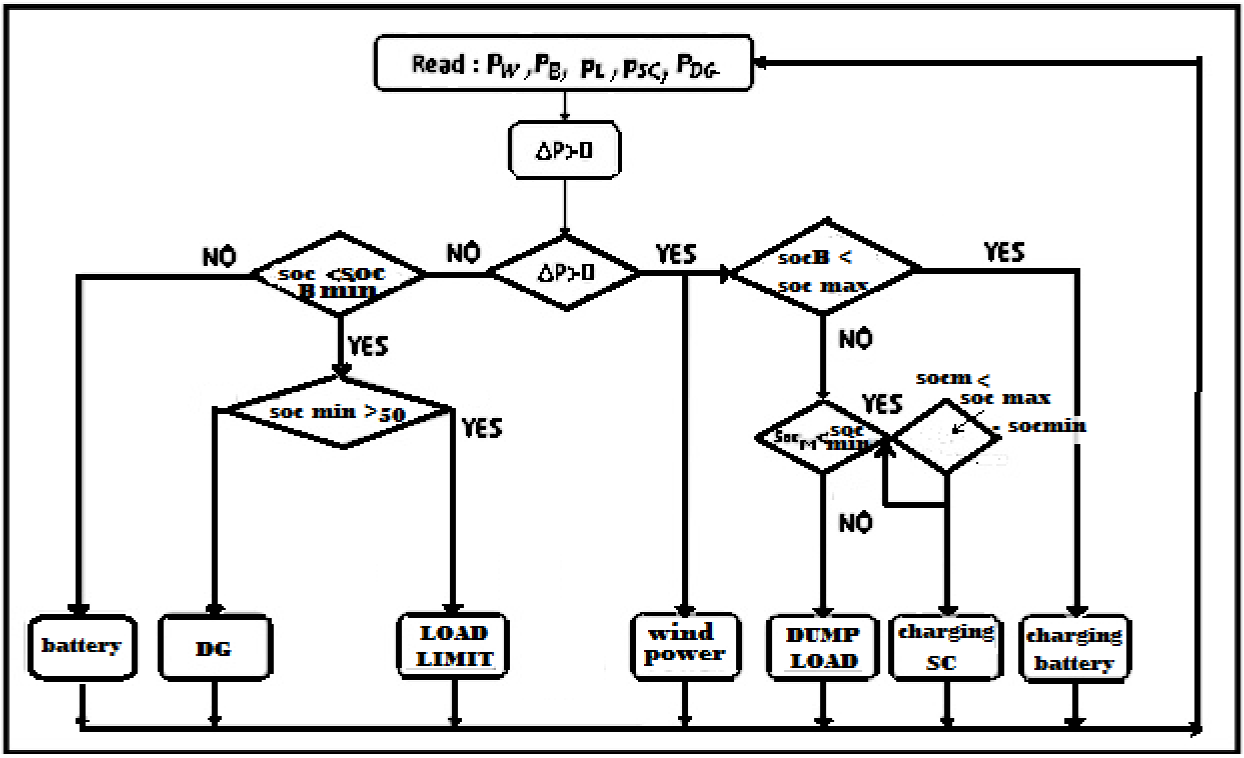

Figure 5. Flow chart of the energy management strategy [3]

The scheme aims to regulate the power in both the directions within multiple grids.The control strategy for the method mentioned here is simple. The error arising due to coupling of grids dwelling in ac and dc segment is very little.

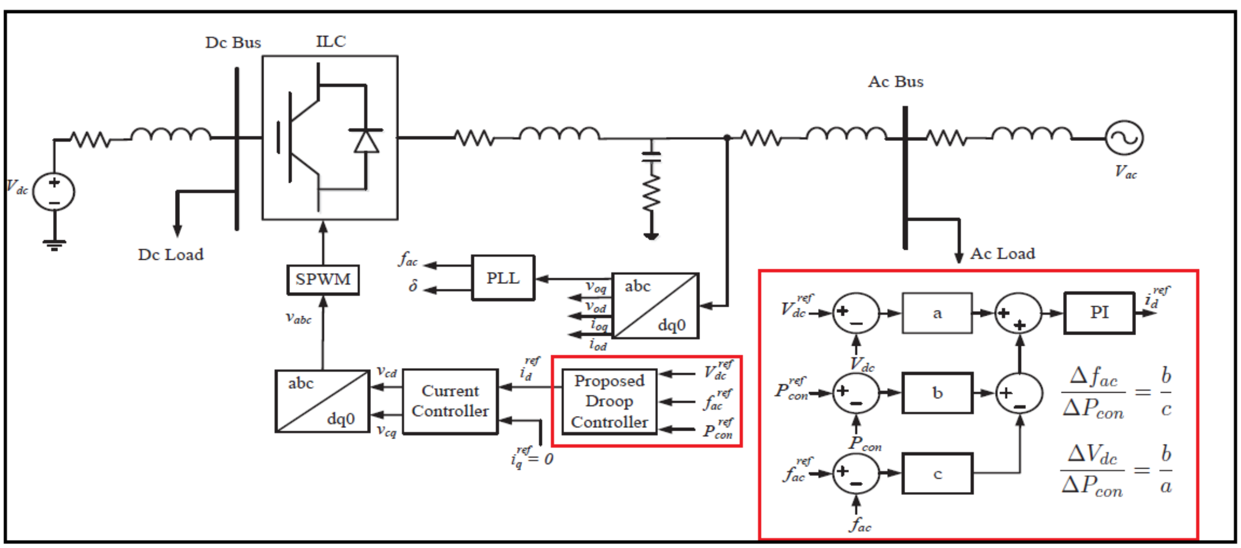

Figure 6. Proposed scale factor based loop controller for multiple hybrid micro grid control where a, b, c represents scale factors

5.The Power Sharing Control for Parallel Inverters [5]

Due to different illumination conditions arising at different places, various rating of PV channel and SOC of battery conditions individual converter delivers unequal power in parallel mode.The bus voltage point of dc mode for individual inverter is monitored. The power delivering capacity to load by each inverter is decided by the parameters ofvoltage to frequency curve method. The suggestion for power equilibrium state for respective inverter is decided on the base of such information.The power divisions in active and reactive mode forparallel inverters are functions of a.c. bus voltage, output voltage as well asangular phasor deviation for inverter response and voltage measured for ac busand impedance angle. The dc bus voltage will drop when inverter is not able to meet load demand. The threshold point of activation of a.c. bus voltage is set based on this reference.Based on this strategy unequal power sharing between the inverter is managed. The control loop structure of the system is shown in the figure7.

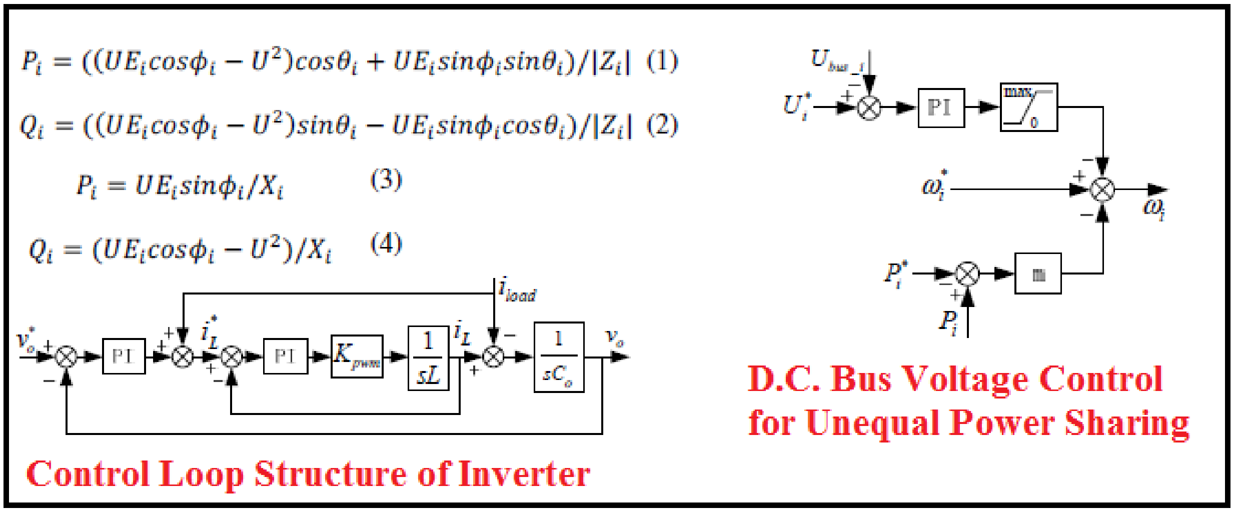

Figure 7. Key equations and control scheme for Power Sharing Control for Parallel Inverters

Apart from this the various control strategy for either the components of the grid or the system as a whole are proposed by various researchers.They are covered very briefly with the below mentioned description.

1. The self-governed operation of interlinking converter by pass the necessity of communicationlayer among distributed generators as well as converter. Various operating conditions are possible when converters are configured in series and/or parallel. The method results in improvement of power transfer capability and reliability conditions.The active filter method improves the power quality of dc bus for hybrid mode operations.
2. Emulation of alternator operation relying on its swing equation to enhance the transient operation in dynamic state and hence to regulate the performance of the interlinking converter.
3. Energy management regulation is conceived to link up distinct working aspects of interlinking converter.
4. The rating and parameters of inverter are rationalized on per unit method. The linear slop of voltage deviation is utilized for the governance of power directions and magnitude among ac as well as d.c. grid such that distinct load demands can be satisfied.
5. The master-slave regulation for collateral interlinking inverters focus on voltage regulation in master mode while for current regulation in slave mode.
6. The control mode forcollateral invertershaving conceptof virtual synchronous generator (VSG).
7. The control strategy on non-counter-current model using energy storage in hybrid role tomaintain the bus voltage within limits.

CHALLENGES

By review of different research papers, the below listed challenges/issues/ limitations/future work points are identified.

1. The enactmentof dynamic energy issuance among distinctdepository unitsof battery ishard to achieve. These methods expects supportingcommunication structureasindispensable part of such structure and in that view communication slow down are inherent portion of it and also calls for sole point-of-failure threat.

2. The aberration of the voltage for bus in virtual impedance linear slope strategyis attainable whendevotedsecondary regulation for bus voltage rebuildup is not implemented.
3. Simultaneous presence of conventional and renewable energy source creates the controlling challenges in voltage of the central grid as well as frequency regulations. This happens because nature of the energy providing sources connected to the grid is different.
4. The conventional loop control strategy expect that the parallel inverters should have equal per unit output impedances' and voltage set point should be same for proportional load sharing. This feasibility is hardly possible.
5. Dump load removal simplifies the structure regulation as well as battery control. Implementation of multiport converter can reduce the switching losses. [2]
6. Control based on Communication scheme can have prompt responseas well as accuracy.Any abnormality observed in controller is going to affect the security conditions and performance of the system.
7. The varying load conditions occurring in ac as well as dc grids impacts the limit violations of frequency along with voltage for the all concernedgrids.
8. The inter link converters are dominantly disturbed.Further,grid-converter distance, load factor change including other parameters plays vital role forslow down response shown by converter.
9. When two sub grids tie together in islanding mode, the stability issues concerning voltage, frequency etc. becomes vital.
10. Management of demand power by participating diesel generator sets in ac and dc sub grid is also a major concern for islanded micro grids.
11. The development in energy storage system which compensates for the fluctuation in power flow conditions in PV cell is also an important aspect.
12. When regulation of voltage for solar plates is envisaged with hierarchical priority it is prone to voltage instability in case the super capacitor fails to meet the momentary current necessity of the load.
13. Power quality issues for low-power PV unit are also of important concern.

SALIENT FEATURES AND DESIGN ASPECTS

The salient features and design aspects of various schemes are described in abridged aspect for the table 1 given below:

TABLE 1 Salient Features and Design aspects of various control scheme.

Control Scheme	Salient Features	Design Aspects
Decentralized Current Splitting	Battery handles steady state component of power Super Capacitor addresses transient power fluctuations	Integration of filter based and basic loop control method
Anti-Windup PI Control	It minimizes the overshoot and settling time	Eliminates the concerns of integral windup
Power Control	Improves reliability and stability of power system when power failure event is addressed	The sensor mode gathers various information and distributed control system (DCS) decides the reference power to be absorbed or delivered depending on dynamic conditions
Novel Loop Based Control Scheme for Multiple Hybrid Micro Grids	Multiple converters in parallel for grid interactions are not required.	Scaling factors a,b,c are introduced which regulates the function of PI controller

The Power Sharing Control for Parallel Inverters	Power status of concerned inverter is swapped on the data processing of bus volt in dc and linear slop relation between voltage and frequency	The startup of regulating action takes place when bus voltage value measured in dc goes down below the set point which initiate the a.c. bus in action.

REFERENCES

1. KaigeZhangandQuanming Luo, “A Filter Modulated Droop Control for Hybrid Energy Storage System in DC Microgrid,” in 2021, IEEE Power and Energy Conference at Illinois,pp.1-5
2. AnnanyaVasanth V VandSheeja V, “Comparative Analysis of SRF, PI and AWPI Controllers for Hybrid Stand Alone Microgrid,”in 2020, International Conference on Power Electronics and Renewable Energy, pp.1-6
3. MojtabaAbbasi, Alexander G. Garganeev and Ari Abdula Rahim, “Control Strategies and Simulation of a Hybrid Microgrid in Grid-Connected and Islanded Modes” in-2020, IEEE 61th International Scientific Conference on Power and Electrical Engineering of Riga Technical University, pp.1-5
4. SarmadMajeed Malik, Yingyun Sun, Xin Ai, Chen Zhengqi and Jamshed A Ansari, “Droop-based Converter Scheme for Linking Multiple Hybrid Microgrids,” in *-2019*, International Conference on Computing, Mathematics and Engineering Technologies,pp.1-5
5. Fenggang Zhang and Jinsong Kang, “A Power Sharing Control Method of Parallel Hybrid Inverters to Preserve Microgrid Stability” in -2019, 22nd International Conference on Electrical Machines and Systems, pp.1-4
6. Sayed Mohamed, Mohamed Mokhtar and Mostafa I. Marei, “A Control Strategy for Hybrid Islanded Microgrid,” in -2019, 21st International Middle East Power Systems Conference, pp.1-6
7. YingmingGeng, MeiyiHou, Liming Zhang, Famgfamg Dong and ZhenJin, “An improved voltage control strategy for DC microgrid with hybrid storage system,” in -2018, 13th IEEE Conference on Industrial Electronics and Applications
8. Wei Yao, Min Chen, Jingjing Chen, Zhaoming and Qian,, "An Improved Multiple-loop Controller for ParallelOperation of Single-phase Inverters with No ControlInterconnections", 2007 IEEE Power Electronics SpecialistsConference, 2007