IEEE Access
Multidisciplinary : Rapid Review : Open Access Journal

Received June 10, 2021, accepted June 14, 2021, date of publication June 17, 2021, date of current version June 28, 2021.

Digital Object Identifier 10.1109/ACCESS.2021.3090266

A Comprehensive Review of Microgrid Control Mechanism and Impact Assessment for Hybrid Renewable Energy Integration

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ABSTRACT This paper describes a comprehensive review of microgrid control mechanism and impact assessment for hybrid grid. Building the model of sustained energy growth is one of the actions to achieve the Sustainable Development Objective (SDO) and change the global fossil fuel system. For co-operation in the development of one independent supplier of renewable energy, the microgrid is essential. Hybrid solar energy microgrid is also a solution for reducing fossil fuel consumption and providing an environmentally sustainable solution to rising rural electricity demand. The most common renewable energy options in the microgrid are solar photovoltaics, wind turbines and biomass. The environmentally sustainable and technologically innovative installation is convenient everywhere. Hybrid microgrid-based renewable energy, however, is confronted, given its intermittent and variable source efficiency, by challenges such as voltage instability, frequency instability, charge malfunction and power quality problems. The paper thus offers a critical overview of the micro grid growth, economic analysis and control strategy.

INDEX TERMS Hybrid renewable energy, grid-integration, control strategy, commercial exploration.

I. INTRODUCTION

The estimated annual demand of global electricity has increased by 5% since 2000 until 2020, as demand has increased for the industry, utilities and residential industries [1], [2]. Fossil fuel, nuclear, green energy and other services are provided electricity. 84.25% of power supply is the primary electricity fossil fuel, 12.3% of renewable energy, 5.3% of nuclear energy, and 2.3% other energy [3]–[5], according to the IEA's 2020 statement. However, the production of fossil electricity, as toxic gases including sulfur dioxide, coal dioxide and greenhouse gasses have been releasing from fossil fuel consumption, has brought global warming and pollution. In addition, fossil fuels are not eternally available, since non-renewable supplies of energy require a considerable amount of time to fill and can be exhausted one day if alternative energy sources are not used [6], [7]. Renewable energy supplies have also been proactively investigated to substitute potential fossil fuels.

The most clean and lasting technology that will replace fossil fuel in the future, since it is not emitting toxic gasses to the atmosphere and to the people in the region, is renewable energy. Examples of renewable energies that can produce electricity include solar, wind, hydro, and biomass, geothermal and tidal. In recent years, renewables were used in particular in the rural regions that are disconnected from electricity grids to satisfy demand for electricity. According to the Global Status Report for Green Energy 26.2% of electricity production comes from renewables, of which 15.8% is hydro energy, 5.5% is wind, 2.4% are solar photovoltaic and

The associate editor coordinating the review of this manuscript and approving it for publication was Qiuye Sun.

2.2% are bioelectric, while other energy sources represent 0.4% [8]. Renewable energy resources (RE) incorporation into the electricity infrastructure has recently become a microgrid application. A microgrid is a distribution-level grid with Distributed Energy Resources (DER), the energy storage facility and the load [9]. This microgrid will work independently if it is disconnected to the grid and not independently if it is interconnected to the grid [8], [10]. DER is a near-distribution energy supply and DER examples include solar power generation, recycling of electricity and fossil fuel [9]. Research shows that there are four categories of microgrid: remote, administrative, military, and microgrid [11]. The advantage of the microgrid in comparison with the traditional power plant is that it provides electricity more environmentally-friendly by reducing transmission power losses, reducing the congestion of the network and enhancing power system reliability [12], [13]. The microgrid can easily provide electricity in rural areas since a transmission line is not necessary.

In addition, the microgrid should provide renewable hybrid energy sources in view of the abundance of energy sources, the need for load and fast installation of the energy storage system of a micro grid and hybrid [14], [15]. Biomass, solar and wind are the fastest-growing Renewable Energy RE, since they are ecologically sound, simple to deploy, and high-tech resources [16], [17]. The sun allows the production of solar energy quickly and photovoltaic solar power is used to absorb and convert sunlight into electricity. In comparison, wind energy transforms power from a wind turbine to an electricity transformation. Electricity produced from biomass or solid waste [18].

As a result, the hybrid electric generation produced from the renewable energy may be distributed as AC, DC, or both. The architecture of the microgrid can be traditional or hybrid microgrid. Furthermore, a standard microgrid may either be an AC microgrid or a DC microgrid, whereas an AC/DC or DC/AC microgrid dependent on the energy sources available and on the loads attached to them can be used as an AC/DC or DC/AC microgrid. A microgrid will supply the DC and CA loads that decrease and increase efficiency in electricity converting compared to different configuration AC and DC microgrid [19]. The combination of renewable hybrid power and the hybrid microgrid needs a robust control plan, since their sources are sporadic, stochastic and varying. The main aim of this study document is to identify the right design, control strategy, and economic analysis for microgrid systems for hybrid biomass-solar solar photovoltaic wind turbines.

The following document is composed as: Section II and III represent the Microgrid architecture of Hybrid Renewable Energy (HRE), followed by Section IV control strategies. Section V presents the battery powered super-conductor magnetic energy systems (SMES), Section VI address the smart control strategy based on fuzzy logic. The control system aspect of the microgrid is discussed in brief in Section VII. The economic analysis is discussed in Section VIII, the future scopes and conclusions of this paper are discussed in Section IX and X respectively.

II. RENEWABLE HYBRID POWER ARCHITECTURE FOR MICROGRIDS

As a consequence of global warming, green energy has become an alternative source of electricity, and this is a microgroup. Biomass, wind and solar are the fastest growing RE, especially solar, which has gained prominence in recent years because of lower costs [20], [21]. In a microgrid, researchers generally use two or three RE sources, so it can be complementary, if a resource cannot continually produce energy over 24 hours. For example, only electricity can be produced by solar power during the day because of the sun. Solar is then hybridized with wind or biomass that allows electricity to be generated all day long. There are also many important components to maintain the device in balance and works effectively in the microgrid architecture including converters, power storage systems and others. However, very few articles from previous works suggested hybrid biomass-solar microgrid photovoltaic turbines architecture. The grid and off grid microgrid architecture are reviewed in this chapter for the purpose of implementing the microgrid Architecture of hybrid biomass-solar photovoltaic-wind turbines.

A. GRID-INTERLINKED MICROGRID

A grid-connected microgrid is a microgrid that operates with the utility grid's presence and can operate in grid-connected mode or islanded mode. There are two configurations in grid-connected microgrid which are AC microgrid and AC-DC microgrid. The details of these configurations are depicted in the subtopic below.

B. AC MICROGRID

The basic architecture of grid-connected AC microgrid typically consists of generation power, converters, AC bus voltage, and interconnected to the grid through Point of Common Coupling (PCC). As seen in Fig. 1, the researchers use battery and supercapacitor to charge and discharge the full output in renewable energy sources and extend battery life. The authors [20] have suggested hybrid solar and wind turbine grid-connected AC microgrid, as seen in Fig. 1. This style of architecture, however, was designed for residential load only. Though the authors have suggested similar to the microgrid architecture [21], the authors use the solar photovoltaics' Maximum Power Point Tracker (MPPT) and doubly induction generator to capture maximum photovoltaic performance and monitor wind turbine generation at variable speed. To optimize solar photovoltaic energy production, a double axis sensor had been applied to the solar photovoltaic system by measuring the path of the sun to the surface of the PH module [22]. Also, in the microgrid system is a diesel generator, but as a backup power only.

In [22], the MPPT was also has been implemented in the microgrid architecture for solar PV same as [21] to ensure it operates on maximum power output. MPPT will adjust the

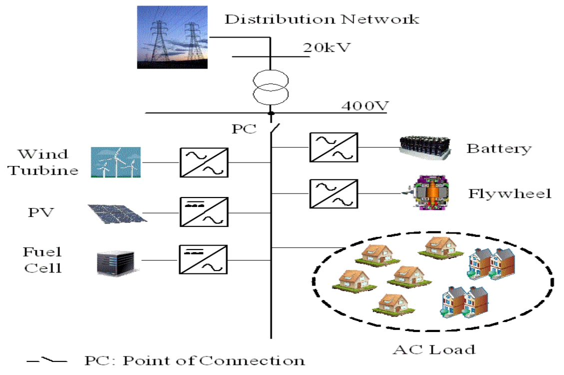

FIGURE 1. Solar Photovoltaic hybrid diagram and AC Microgrid-connected wind turbine network.

operating point of solar PV to obtain the maximum power available from the PV array at any given time [23]. However, some MPPT algorithms might track in the wrong direction and lead away from the MPP itself by rapidly changing the degree of irradiance and temperature [24]. It is therefore very important that the new MPPT is developed that can adapt to evolving operations rapidly.

C. AC/DC MICROGRID

AC/DC microgrid is a combination of AC subsystem and DC subsystem in a system. The AC/DC power can receive and provide power either in AC or DC. As shown in fig. 2, the authors [25] suggested a grid-connected DC-AC solar hybrid photovoltaic-wind turbine system. The AC / DC interconverted connect the AC bus and a DC bus such that voltage is fluid and energy output is maintained. DC/DC transformer, boost converter and AC/DC converter are connected to the DC bus, the battery power storage facility, solar photovoltaics and wind turbines. The use of multiple converters in the device, however, may increase the cost of the microgrid project which will impact the economic viability of the microgrid.

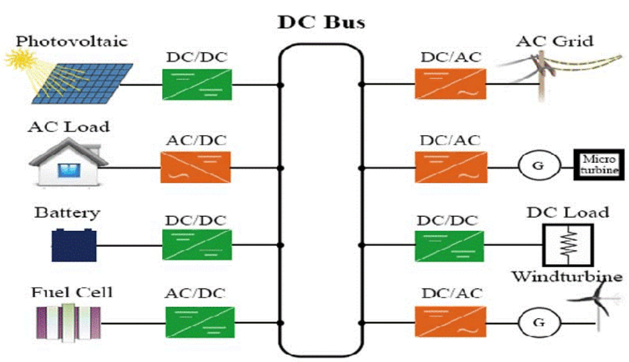

FIGURE 2. Hybrid DC-AC Microgrid Architecture attached to the solar Photovoltaic-wind turbine.

The Combined solar photovoltaic and wind turbines grid-connected AC/DC microgrid was also proposed in [26]. The various microgrid architectures, which the authors proposed [25] are different from the converters, are to add the full photovoltaic power tracker and wind turbine with Permanent Magnet Synchronous Generator (PMSG), to operate for optimum production of energy in those areas, irrespective of the weather conditions. PMSG is the growing trend of wind turbine-connected directly with a low-speed wind turbine to improve productivity in order to lower the costs of wind turbines [27], [28]. However, PMSG can only be used for the optimum performance of the variable speed wind turbine. Contrary to others, [29] have proposed an AC-DC microgrid consisting of three renewable energy sources: solar photovoltaic, wind turbine, and biomass. Fig. 3 illustrates the proposed microgrid architecture. Solar photovoltaic and wind turbines are attached to the DC bus through several input energy conditioners to prevent conversion to several AC/DC. Bidirectional DC/AC transformer connects the AC bus and DC bus.

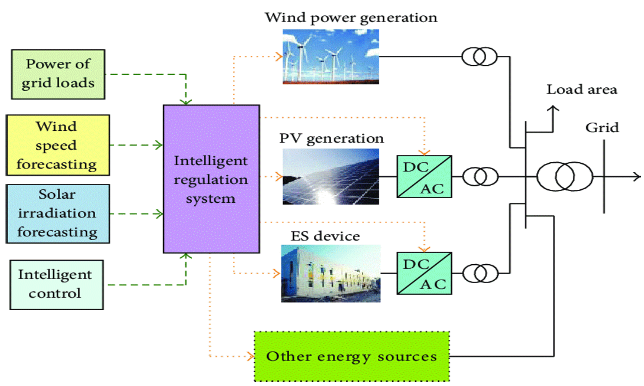

FIGURE 3. Photovoltaic solar hybrid wind turbine DC-AC microgrid.

The AC/DC grid-connected microgrid proposed in [29] consists of the photovoltaic solar energy system, the fuel cell, the PMSG fuel and wind turbines. For rotational speed and full wind turbine capacity, PMSG was used in the wind turbine system. A DC/DC boost converter and battery storage facility, connected to all renewable energy sources by buck-boost converters, were used to control the two-way power stream. The DC bus voltage to AC voltage is converted with a pulse inverter. Table 1 shows comparisons of the architecture of the Renewable Energy Sources (RES) grid-connected microgrid.

III. OFF-GRID CONNECTED MICROGRID

Off grid-connected or islanded microgrid is operated without the presence of a utility grid and run in stand-alone mode. The detailed architecture of off-grid microgrid is discussed in the next subtopic.

A. AC MICROGRID

In [32] and seen in Fig. 4, we suggested a grid-connected hybrid biomass power station, Wind Turbine (WT), batteries, diesel generator. The company has proposed the installation

TABLE 1. RES based grid-connected microgrid architecture comparison.

	Architecture				
Ref	Primary Sources PV/WT/BM	Secondary Sources DG/FC/Battery/SC	Converters AC-AC, DC-AC, Bidirectional and Buck-boost converter	Configuration	Description
[13]	✓	✓	✓	AC	Battery storage hybridization of the super-capacitor
[16]	✓	✓	✓	AC	Diesel generators used in WT for maximum power generation are reserve power and DFIG
[17]	✓	✓	✓	DC	To gain full power from solar PV MPPT is introduced
[20]	✓	✓	✓	AC/DC	Used by the interconverter, the voltage between AC and DC bus is reduced.
[22]	✓	✓	✓	AC/DC	For PMSG solar PV and WT, MPPT is added.
[24]	✓	✓	✓	AC/DC	To control rotational speed for tracking maximum power in WT PMSG was included in the wind turbine system
[30]	✓	✓	✓	AC/DC	A dual-axis tracker has been introduced in PV to optimize performance
[31]	✓	✓	✓	AC/DC	Biomass gasifier is the system's least priority and battery banks will eliminate RE sources intermittent

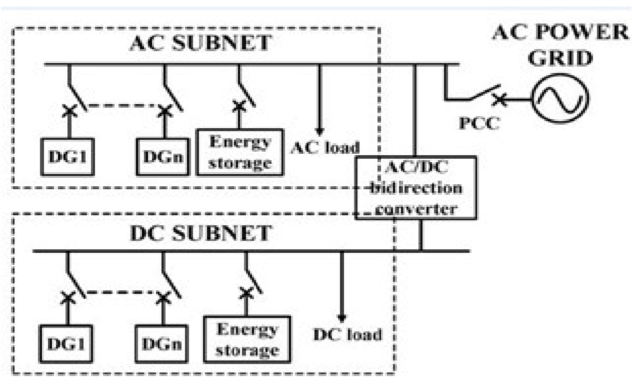

FIGURE 4. AC microgrid for off-grid link hybrid biomass and wind turbine.

of a biomass cycle biomass plant in organic Rankine because of its higher cycle performance, low maintenance and easy start-stop process. A diesel generator has been used as main power in this architecture to meet the instantaneous net charge but with a lower setting to enable biomass and WT power usage. Biomass, meanwhile, is an additional fuel that reduces the use of diesel generators and WT has been used to achieve full power in the microgrid. This HRE microgrid was proposed for windy areas only, as generation of electricity was largely dependent on WT.

B. DC MICROGRID

Emerging of DC microgrid was started when there is a DC equipment trend in residential and commercial areas. In order to avoid multiple conversions in the electrical system, a DC microgrid was established for better efficiency and reliability [33]. The authors [34] have thus suggested a solar pv, battery, dc/DC converter, VSC, and two-directional conversion to DC microgrid in off-grid connected mode. There are two units in DC's microgrid architecture: hybrid unit, and wind turbine-generation (WTG), as presented in Fig. 5. A voltage source converter can link this hybrid unit to the DC-bus, and can change the voltage via the voltage source controller and WTG connecting to the DC-bus via a DC/DC converter in order to keep the WTG power flow load. For further development, the WTG unit may be equipped with a battery energy storage system in order to prevent wind turbine power waste.

C. AC/DC MICROGRID

AC/DC Off-grid-connected microgrid may have a separate grid-connected configuration as the device is in stand-alone mode. For the researchers to progress in the future, the off-grid AC/DC microgrid assessment is important. The authors [30] also suggested a method of bio gasifying biomass with solar, wind turbines and off-grid microgrid AC/DC battery systems for India, as presented in Fig. 6. The recommended biomass gasification system extracts from solid biological residues into gas fuel for electricity generation. Solar PV, battery, and dump load link the load, wind turbine, and biomass gasifier to the AC bus. The battery-attached charge controller maintains energy flow and limits the charging and discharge rate of batteries in this architecture. In [35] suggested off-grid microgrid hybrid solar

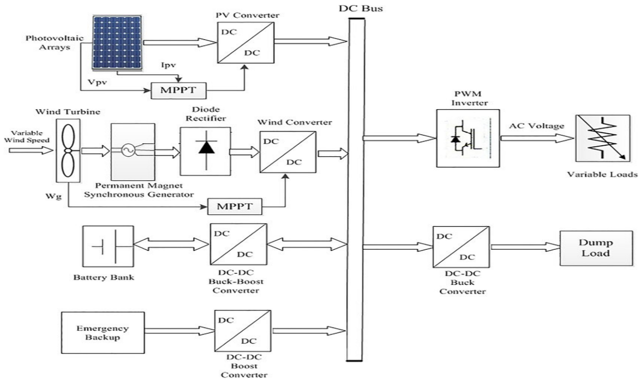

FIGURE 5. Solar-wind DC microgrid hybrid architecture in off-grid linked mode.

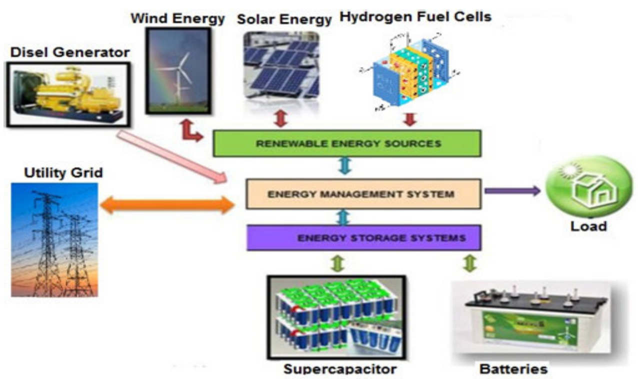

FIGURE 6. AC-DC hybrid biomass solar microgrid in the off grid paired PV wind turbine.

photovoltaic, WT and diesel generators. The diesel generator acts as a backup energy in this architecture, where the power produced by solar PV and WT is inadequate. In [35], micro grid design consists of solar photovoltaic, wind turbines, diesel generators, batteries and converters. Then [31] have proposed that the Synchronisation Generator (SG) DFIG should be coupled with in [35] for additional power generation in wind turbine operation as well as [21] for wind turbine operation. However, only high wind speeds that would be disadvantageous when the wind level was poor would use this system in a wind turbine. Table 2 presents the contrast of the architecture of the RES off-grid wired microgrid.

D. ARCHITECTURE PROPOSED FOR THE PHOTOVOLTAIC-MICROGRID HYBRID BIOMASS-SOLAR

Tesla, ABB and several other businesses that sell bundled systems with varying power ratings to both industrial and private installations are using the new german pattern AC microgrid. AC microgrid is a safe technology, since it has been developed, easily designed and installed in the power system. AC microgrid should stop any serial-connected converter in grids-connected mode because the power flow from/to the grid has a high degree of reliability. The main downturn for AC Microgrid is the need to synchronize the dispersed energy supplies of several control electronics interfaces with the AC Network [40].

The hybrid photovoltaic solar-biomass wind turbine, owing to the incorporation into a structure, is the unusual mixture of renewable energy options into the microgrid. For example, voltage stability, frequency stability, power flow control and reliability are a challenge. However, in [29], [30], [41], researchers are actively investigating the possibility of the inclusion of a combined photovoltaic-wind-biomass solar photovoltaic-microgrid turbine. The above-mentioned discussion show that the most optimized hybrid storage architecture is a Microgrid Connected/Off-grid Hybrid-Biomass-Solar PV Turbine, an AC/DC grid connected, DFIG, MPPT.

To offset the downside of battery, such as slow response and longer battery life, a hybrid energy storage device such as super capacitors and batteries is essential. The DC/DC Converter significantly increases input voltage and output voltage to improve the performance of the input DC source [42], [43]. In order to preserve the dynamic control and to assist one another in improving the balance of power between them, a bi-directional converter is connected between ACs and DC busses [44]. Throughout the grid linked and off-grid connected microgrid, hence hybrid energy storage devices, DC/DC converter, and bidirectional converters are important elements.

IV. MICROGRID CONTROL SCHEMES FOR HYBRID RENEWABLE ENERGY

For the microgrid system planning process, the control strategy for mixed renewable energy sources in the microgrid system is central to ensuring system reliability. In this article, the technique for microgrid control is divided into three components, voltage control, frequency control and power monitoring. Power management is required to solve the fluctuating efficiency of energy output and the variable energy requirement on the charge side. Frequency controls were often designed to mitigate unequal strength between generation and cargo, low inertia and lack of a motor with revolving or renewable resources. In addition, power flow management is necessary to minimize the quality of the microgrid power because of the renewable energy fluctuation, the harmonic distortion, frequency and variation in voltage. All these controls are supplementary in order to maintain the reliability of the microgrid capacity of hybrid energy before the load is achieved. No special work on these three control methods from previous studies is however available for hybrid biomass-solar photovoltaic-wind turbine microgrid as shown in Fig. 7. This section therefore included a thorough analysis of the techniques of voltage, frequency and power.

A. VOLTAGE CONTROL

Voltage instability usually happened off grid connected because it is disconnected from utility grids and only depends on renewable energy sources. Due to intermittent renewable energy sources and power mismatch between load and generation, voltage instability happened. Thus, many researchers have proposed voltage control in the microgrid system to

TABLE 2. Summary of the voltage control Scheme.

Control Scheme	RES/ Operating state	Microgrid Configuration	Short Description	Restriction	Ref.
MPCP/MPVP	PV-WT/ Grid-connected	AC/ DC	MPCP - bidirectional dc/dc power controller MPVP– interlinking AC/DC controller	Additional calculation in the proposed control system would necessitate the use of sensor and communication facilities.	[25]
PID Controller	PV-fuel cell/ grid connected	AC	Keep the parameters under the limit by using a voltage controller, voltage source inverter, and PID.	At a higher load, voltage regulation cannot raise the input voltage to get the desired output voltage.	[36]
BESS + Consensus Protocol	PV/off-grid connected	DC	In terms of SOC and terminal voltage, regulate the super capacitor and battery.	✓	[37]
Control strategy of battery and SC	PV-WT/off grid- connected	DC/AC	SC uses the high-frequency power portion to compensate for battery current.	✓	[38]
UII-LTCL	PV-WT/grid and off grid-connected	AC/DC	To boost voltage output in the ac subsystem, use SVR and NSVR control methods.	✓	[39]

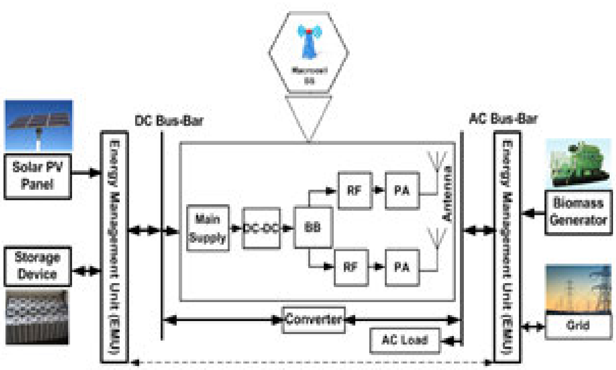

FIGURE 7. Hybrid PV-wind turbine for biomass solar architecture of AC-DC microgrid in the grid mode.

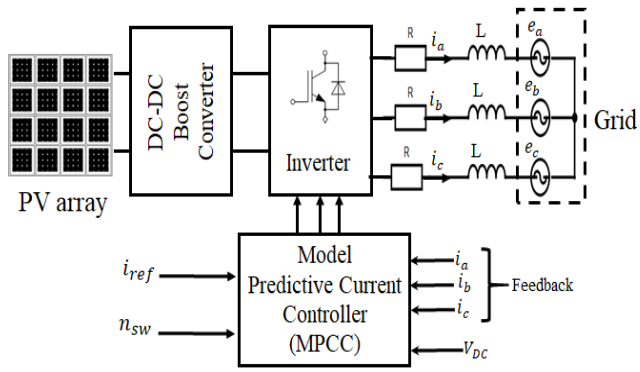

FIGURE 8. MPCP block diagram on dc-dc conversion bidirectional off-grid mode.

mitigate these problems and ensure the reliability and efficient operation of the microgrid. Comprehensive voltage control from previous research is reviewed in the next subtopic.

B. MODEL CONTROL PREDICTIVE (MCP)

The role of dc energy sources in micro grids, such as Photo-Voltaic (PV), fuel cells, energy storage, and DC loads, prompted researchers to investigate AC-DC microgrids. Therefore, AC/DC microgrid power is extremely difficult to manage. In the past, microgrid DC-DC converters and interlink converters have also been used to power the input circuit of internal and external voltage via Proportional Integral Derivatives (PID) controls. In addition, they often serve as a conventional technique. In [25], MPC is developing into two policies, the Modern Predictive Current & Power (MPCP) and the PID, without using the Proportional Integral Derivative. MPCP is used for smoothing green energy output by managing the bi-way dc-dc battery energy storeroom converter and stabilizing the DC bus. Fig. 8 displays the MPCP power system diagram.

The battery power balance can be determined by the MPCP control as given in eq. 1.

$$P'_{BESS}(k+1) = I_{DC}(k+1).V'_{DC} \tag{1}$$

where, V'_{DC} is the reference voltage in DC bus, I_{DC} is the current feeding to the BESS. The current flowing can be computed as given in eq. 2.

$$I_{DC}(k+1) = I_{RES}(k) - I_C(k+1) - I_{ROM}(k) \tag{2}$$

where, I_{RES} is the renewable energy current, I_C is the current of DC side capacitor and I_{ROM} is the current passes into dc load and inverter. The performance of the battery can be predicted as given in eq. 3.

$$P_{bac}(k+1) = I_B(k+1) \cdot V_B(k) \tag{3}$$

where, P_{bac} is the battery power, I_B is the battery current, V_B is the battery voltage.

In the meantime, MPVP manages the AC/DC connector converter to ensure that the microgrids power supply and power flow is secure. As seen in Fig. 9, MPVP control can also be split into two modes, which are island and grid-connected. MPVP regulates the voltage of the condenser in the islanded operation to provide stability of AC voltage and grid operation. For dc loads, MPVP serves to stabilize the DC bus voltage and to link the microgrid to the central grid. In short, MPC is deployed on the converter DC/DC and on the converter AC/DC to allow for renewable energy production and to maintain simultaneous DC and AC bus voltage. However, more measures are required to strengthen the MPC strategy such as sensors and connectivity facilities.

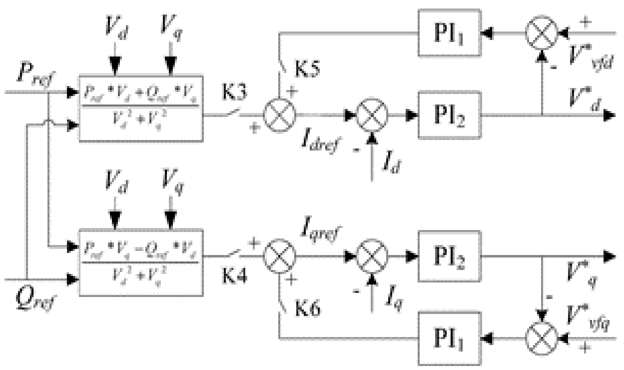

FIGURE 9. DC-DC converter block diagram of MPVP on connecting switch a) off-grid mode b) grid-linked mode.

C. REGULATION OF VOLTAGE PID

The authors [36] suggested a control technique for frequency and voltage control to control the voltage of hybrid photovoltaic and AC microgrid panels. They showed key parameters, mathematical analysis and controls of test components. In order to ensure reliability of voltage and frequency, several parameters were investigated, such as voltage stability, frequency, load sharing, and active and reactive control. The researchers suggested that voltage controls can be located on each DER to provide stabilization in the region based on this fundamental parameter. In order to analyse the voltage control methods on various load demand and power sources for distributed generation for statistical analysis, the power equation, active power, reactive power, apparent power, condenser, inverter, and per-unit value are measured. In addition to controlling network voltage, frequency, and power output, the voltage source inverter is used in monitoring modules.

As shown in the microgrid block diagram, the Phase Locked Loop (PLL) in the control portion synchronises the grid voltage, and the voltage is scaled by the input signal. In short, this proposed control paper can increase and decrease the voltage values in the microgrid device according to the voltage requirements. The suggested control cannot, however, increase the input voltage, such that the desired output voltage is increased, and will rectify the voltage control because the control threshold is exceeded.

D. HYBRID ENERGY STORAGE SYSTEM CONSENSUS PROTOCOL CONTROL

Voltage stabilization can also be accomplished using an energy storage system, but previous researchers have found that it is not efficient to use an energy storage system like a battery because it has a small ramp rate. Thus, they propose hybridization of energy storage systems to reduce the voltage stability and extend the battery life by equipping a super-capacitor or Ultra capacitor. From [45], [46], in order to enhance the voltage output and ensure average tension of the DC buses inside the device is controlled at the benchmark value, the combined battery and super-capacitor has therefore been suggested in [37] as a hybrid energy storage system control. The consensus protocol scheme also guarantees that the voltage control is equally essential for all power storage systems. This consensus control scheme is split into multiple controls composed of a battery controller. The battery controller controls the state of the battery and retains the voltage of the terminal of the super-capacitor. In Fig. 10, the external battery, SC terminal, and SOC controller for the generation of the internal current-controlled loop reference charging current are shown. The formula for super-capacitor terminal voltage is as given in eq. 4.

$$G_{SCVC} = K_{PSCVC} + \frac{K_{ISCVC}}{s} \tag{4}$$

where, K_{PSCVC} and K_{ISCVC} are the proportional and integral gains.

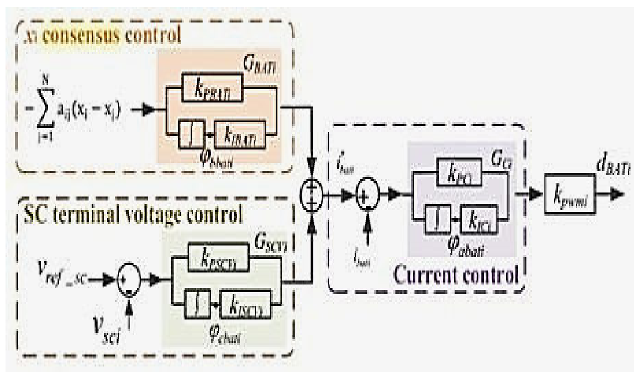

FIGURE 10. Diagram for battery controller.

By calculating the battery error time and switching to a proportional integral (PI) for the actual adjustment before the SOC reaches the boundary value, the consensus protocol will avoid overcharging or deep charging of the battery. Then, in the super-capacitor controller DC bus voltage and super-capacitor terminal voltages, as seen in fig. 11, are held by the consensus protocol. Super-capacitor manages the average voltage of the DC autobus and treats errors by a transfer mechanism called PI controller as given in eq. 5.

$$G_{Ui} = K_{PUi} + \frac{K_{IU}}{s} \tag{5}$$

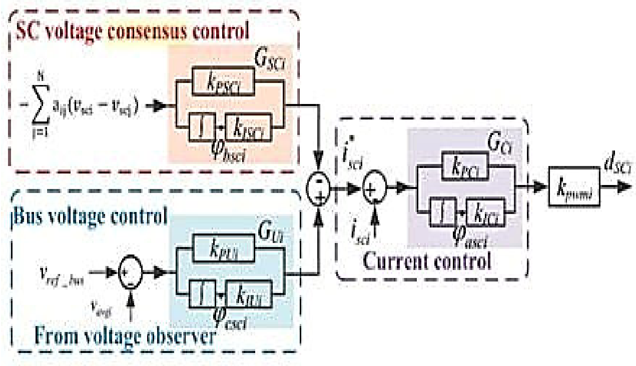

FIGURE 11. Block diagram for SC controller.

where, K_{PUi} and K_{IU} are the proportional and integral gains. For several super-capacitor voltage controllers, the consensus protocol establishes a difference between its voltage and that of its neighbors in order to define an errand word and feed it to the PI controller through the transfer mechanism as given in eq. 6.

$$G_{SCi} = K_{PSCi} + \frac{K_{ISCi}}{s} \tag{6}$$

where, K_{PSCi} and K_{ISCi} are the proportional-integral gains.

In short, a hybrid energy storage device controls the DC voltage in the microgrid. The average DC bus, the terminal voltage and the battery SOC are factors aimed at reaching agreement on the increase of voltage and the avoidance of SOC violations. The authors [38] took the same approach, but used a different strategy, to increase reliability of voltage by battery and super capacitor. To minimise the voltage difference and produce the total reference current, the benchmark voltage and true grid voltage are linked together, and the voltage difference is applied to the PI controls. The real battery current is then matched with the reference current. In order to minimize the current difference, different existing batteries are converted to PI controls and battery control signal generated. However, the reference current cannot be pursued due to inertia and a super-capacitor compensates for the battery power as given in eq. 7.

$$I_{SC_{ref}} = (I_{HFC} + I_{Batt-err}) + \frac{V_{Batt}}{V_{SC}} \tag{7}$$

where, $I_{HFC} = I_T - I_{Batt-ref}$ is the high-frequency component of total reference current and $I_{Batt-err} = I_{Batt-ref} - I_{Batt}$ is the battery current error because of poor battery dynamics.

The control technique suggested that the AC-DC microgrid DC bus tension be regulated off the grid connection by monitoring power fluctuations. The battery and the super-capacitor work together to decrease the rapid fluctuation of battery power and then reduce the battery charging/discharge rate. This improves the voltage control efficiency and also regulates the SOC of the battery.

E. INTERACTIVE INVERTER (UII) UTILITY WITH LTC-L POWER STRATEGY. INDUCTOR, CONVERTER, CONDENSER AND INDUCTOR

During this period, AC-DC was the leading microgrid topology, with most renewable energies and different loads being DC dependent. Thus, converting AC to DC, DC to AC is necessary with a converter / inverter. However, these transformations deteriorate the power output of the microgrid. Thus, [39] proposed control techniques for using an interactive inverter (UII) with an inductor, transformer, condenser and inducer for both a grid-connected as well as a microgrid-connected grid (LTC-L). The AC/DC microgrid typically comprises an AC and a DC bus linked to a two-way converter. The system's LTC-L supports absorbing nonlinear load in non-grid connections and removes the frequency in the microgrid connected to the grid. Fig. 12 reveals LTC-UII L's management strategy system.

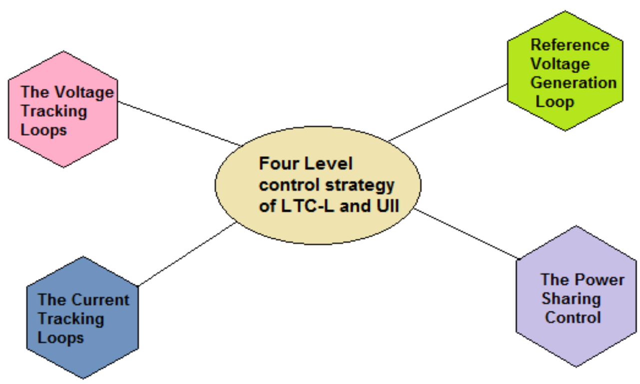

FIGURE 12. Structure for control strategy off LTC-L UII.

The consensus protocol and model predictive control strategy for a hybrid energy storage device are the best options for incorporating the photovoltaic-solar hybrid biomass microgrid to ensure tensile stability in buses, according to the researchers' previously suggested voltage control strategy. By detecting the battery error, the consensus protocol management technique will avoid overload of the battery. The consensus protocol is an appropriate approach compared to other control methods because it does not require complex algorithms like MPC, UII-LTLC and PID. The DC micro grid system can also be controlled using the hybrid Energy Storage System application, which is composed of a battery and a super condenser with a consensus protocol management strategy. By regulating the power converter that works for smoothing voltage between AC and DC busses in an AC/DC microgrid, MPC may also play a role in voltage stabilization.

F. FREQUENCY CONTROL

Frequency fluctuations in electricity grids occurred due to unequal capacity from generation to charge because of varying demand profiles and the irregular presence of renewable sources of energy. The microgrid condition is also exacerbated by a low inertia and the small-time constant [47].

In addition, certain electronic power interfaces will require the use of different distributed generators such as solar, wind, etc in the micro-grid structure. Responsive to frequency shift are these control electronic devices. It also increases the microgrid's sensitivity to power turbulence [48]. Further, there was frequency volatility within the green energy microgrid as the main contributor to non-grid inertia was lack of spinning machines in the traditional grid. The power exchange between the microgrid and the main grid stores the unit's frequency. However, because of the proximity of the main grid and uncontrollable renewable energy supplies the frequency stability in the off-grid microgrid is difficult to maintain. The current researchers have also conducted several experiments on frequency modulation.

V. BATTERY POWERED SUPERCONDUCTOR MAGNETIC ENERGY SYSTEM (SMES)

In [48], in the primary frequency control (PFC), the battery-mounted SMES is integrated into the system to adjust the frequency of the system and to prolong the life of the battery. The relation between device frequency and power disruption is determined by traditional primary control as given in eq. 8.

$$\frac{df}{dt} = \frac{f_0}{2\sum H_I}\left(\sum P_{G_I} - \sum P_{L_I}\right) \tag{8}$$

where, $\sum H_I$ is the number of continuous inertia for I system, and f_0 is the system setting frequency.

Battery SMES improves regulation of primary frequency by constant cell inertia and counteracting frequency fluctuation via the equation of drop regulation as given in eq. 9.

$$\frac{df}{dt} = \frac{f_0}{2\sum H_I}\left(\sum P_{G_I} - \sum P_{L_I}\right) + D \tag{9}$$

where, $D = D_{SMES}\Delta P_{SMES} + D_{Battery}\Delta P_{Battery}$, D_{SMES} and $D_{Battery}$ are SMES and battery device drop coefficient.

In the HESS, SMES acts as the power absorption and the battery is a power buffer, which helps SMES to flourish at low energy levels. The drop factor shown in the Fig. 13 controls the SMES to load or unload more fuel, faster than the batteries. The author mentioned the limitation of the objectives, since at various times it should be the SMES and the battery that have different behaviour. The drop regulation is usually applied to adjust its power point to frequency difference from nominal value with a diesel generator. The SMES and the battery system in an Off-grid DC microgrid were changed shortly to monitor the drop. SMES and micro-grid frequency stabilization are safer than a micro-grid battery since under varied power conditions they can have the optimal energy output. However, owing to device complications, optimum drop control benefits are difficult to discover.

A. VIRTUAL SYNCHRONOUS GENERATOR (VSG)

Another monitoring technique for frequency control with a microwave adaptation, the Virtual Synchronous Generator (VSG), offers inertia in the stabilization system the imitation synchronization generator (SG). VSG was operated

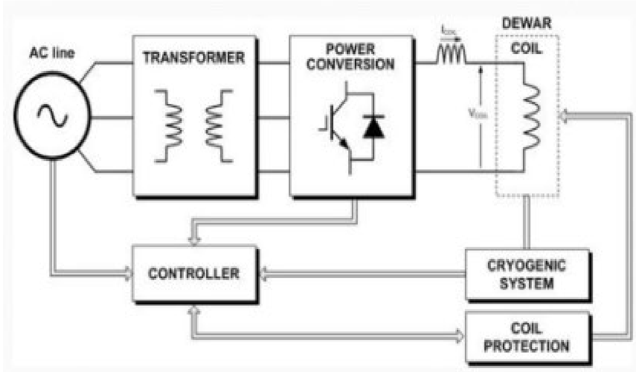

FIGURE 13. Control system for SMES and battery hybrid microgrid.

by virtual rotor, inverter, and virtual secondary controller (PI controller), as seen on fig. 14, using [49]. VSG is controlled by virtual controller. This paper uses Particle Swarm Optimization (PSO), which improves the reliability and durability of the solar power systems, to find the optimum tuning of the virtual controller. In order to simulate the inertia reactions into green energy systems, the virtual control emits a VSG control signal. In [50], on the other hand, a VSG device with inertial and damping features was proposed for the production of virtual inertia during variation in high frequency.

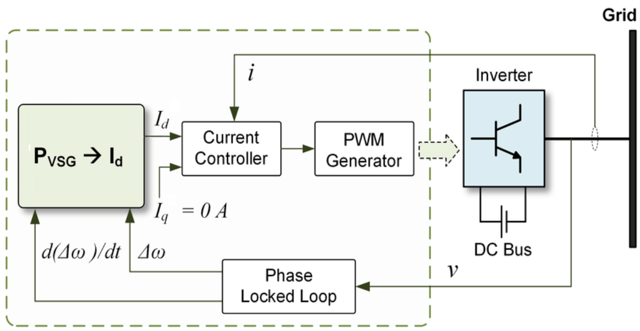

FIGURE 14. Block Diagram of VSG.

In assumption, [49] proposed VSG-based frequency control, consisting of virtual templates, virtual primary controls and virtual secondary controls, to give some inertia to the control system loop and maintain the microgrid frequency. This paper has been developed to optimally simulate the inertial reaction of the power system by the PSO algorithm VSG. The authors [49] have proposed a detailed PSO frequency control strategy and new coordinate systems between the VSG and the Optical Over/Under Frequency Relay based on frequency control, in order to enhance the stability, compared to [50].

VI. SMART CONTROL STRATEGY BASED ON FUZZY LOGIC

The frequency variation was caused by the smaller energy present from the generator in the traditional Grid in an off-grid-connected hybrid micro grid renewable energy. A smart logic control technique on the frequency and voltage

TABLE 3. Frequency management plan summary.

Control Scheme	RES/ Operating state	Microgrid Configuration	Short Description	Restriction	Ref.
With a dynamic loop, SMES and battery	WT-PV/off-grid diesel generator	DC inertia constant and counteracting frequency fluctuation with droop power, SMES and battery improve primary frequency control.	By increasing the device droop factor for various units is difficult.	Finding the best	[48]
VSG	PV-WT/off-grid thermal power plant	DC	PSO regulate the VSG	✓	[49]
Fuzzy logic	WT-PV	AC- DC	Frequency modulation by battery control on the basis of active and reactive capacity	✓	[51]

stability in off-grid Microgrids was put forward in [51]. Active, reactive power was taken into consideration, since a small difference from this technique will lead to consistency in frequency and voltage. When the active power increases and a bidirectional dt/dc boost converter is made that provides a fugitive logic-based controller with short power. The frequency decrease is sensed. The frequency/voltage management system contains the input parameters frequency, voltage and loads, while battery charging, battery discharge, dump charging and secondary charging are the output parameters. A Fuzzy logic control is used, in conclusion, to maintain voltage and frequency consistency, as a battery energy storage device for supervision. The battery is unloaded or charged to maintain the frequency and voltage constant all the time, as the charge increases in accordance with the fuzzy logic monitoring control scheme. In general, in the grid-connected microgrid there is frequency volatility because of the low relative mass inertia and the high renewable energy permeation. The VSG and the fuzzy based logics are the better mechanics for control the device frequency in the system, since they are easier to implement than the SMES system and are based on the frequency control solution description in Table 3 and the complicated battery loop description. Researchers believe it is difficult to determine the optimum drop factor and high drop gains will trigger micro-grid instability to achieve accurate power-sharing. VSG will be involved with PSO in replacing the role of SG in a standard grid that compensates for the low inertia of frequency stabilization, and battery-based, battery-based frequency control will be assisted by the fuzzy-based logic control. The logic control technique VSG and fuzzy are thus responsible for ensuring reliability of the system's off-grid link frequency.

A. POWER FLOW CONTROL

Power flow control from the previous research is examined in this topic. Similar to voltage and voltage volatility, the difference in power flow arises by the combination of intermittent, high power and size renewable energies. In the next subject, therefore, micro grid power flow control was examined to improve the microgrid power efficiency.

B. HYBRID BAT ALGORITHM AND DRAGON FLY ALGORITHM (HBDFA)

The authors [52] proposed combining the Bat algorithm (BA) and the Dragon Fly Algorithm (DFA) for the PID controller. Since the feeding position in the power grid is positioned in this way, the BA algorithm imitates bat behaviour when moving error and value from BA to DFA. In the meanwhile, DFA receives BA's output and generates the best value for the PID controller of the current reference to optimally monitor the current reference. Therefore, when the PID control parameters have been calibrated, the controller will monitor the reference signal for a short period of time and increase the dynamic efficiency of RES. The gate signal is then produced and provided to the inverter in order to deliver the required voltage to ensure optimum power supply for the device. One of the benefits of hybrid PID controllers based on BA and DFA is that they work well even though the source or load side differs. The hybrid BA and DFA will therefore provide the optimal power flow management in the connected grid by improved control precision with less time and improved performance.

C. BI-DIRECTIONAL POWER TRANSFER STRATEGY BASED ON HYSTERESIS AND HARMONIC FILTER REGULATION

Fig. 15 shows a hysteresis-based bidirectional power transmission technology with a power harmonic filter proposed in [52]. The RLC element's power harmonic filter will reduce system harmonics and improve system stability. When the AC microgrid is distorted, the inverter and AC microgrid connect harmonic control filters to provide harmonic compensation. This shows that when the power harmonic filter is used, the total harmonic distortion (THD) has been decreased. Inverter lateral power flow mode and DC/DC lateral power flow mode converter are both used to track the hysteresis based two-way power flow. Using the inverter power flow mode, the DC microgrid draws electricity and then converts the energy to AC using the DC/ DC converter voltage at the appropriate frequency and voltage. The grid tension is balanced in DC/DC side mode, and the DC voltage changes to the grid for power restoration in the DC network according to the DC micro grid specifications. The suggested technique also reduced harmonic distortion by using a power harmonic filter and improved performance caused by the DC/DC converter. The control flow of the system has also been improved via the two-way power transfer technique. However, a power efficiency algorithm is used in the bi-directional control.

TABLE 4. Frequency management plan summary.

Control Scheme	RES/Operating state	Microgrid Configuration	Short Description	Restriction	Ref.
HBDFA +PID	WT-PV/grid connected	AC	Monitor the PID controller output value for tracking current relation	Present distortion of signal amplitude occurred	[54]
Bidirectional hysteresis power transfer + harmonic power transfer	WT+PV/grid linked and off-grid	DC-AC	Minimizes harmonic though disturbed Inverter and dc/dc transformer power hysteresis	Need a decent power efficiency algorithm	[31]
SSWO	PV-WT-fuel cell connected to grid	DC- AC	Active and reactive power control convert, inverter between load and source side	✓	[45]

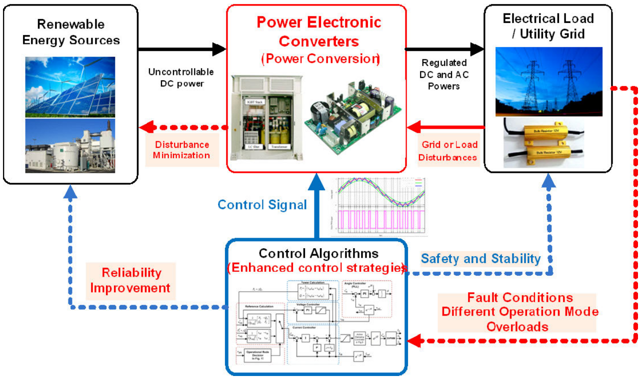

FIGURE 15. Regulation of two-way power flow.

D. HYBRID SQUIRREL SEARCH ALGORITHM AND WHALE OPTIMIZATION ALGORITHM (SSAWO)

Electricity efficiency is critical to prevent system losses, service outage, over-heating and system failure in the combined clean energy microgrid. Therefore, [53] proposes the power flow control system for the grid-bonded microgrid to manage the voltage converter and deliver sufficient actual and reactive energy using energy storage to enhance control strategy. The SSAWO algorithm for hybrid squirrel research and whale optimization (SSAWO) is used. The SSA algorithm paralleled the online control indicator and regulated the control signals for the voltage source inverter based on the variety of power exchanges between the source and the load side. Based on the modification of PI controller acquisition parameters, SSAWO was able to achieve the best power flow and system error using the proposed scheme.

The bidirectional power transmission and power harmonic control strategy is, in accordance with the overview of the power flow control strategy in Table 4, best suited to ensuring maximum power flow inside the grid and off the grid. Power harmonic filters can easily reduce THD and keep it down, which reduces power consumption, lowers peak current, and increases system performance. Bi-directional hysteresis power conversion, on the other hand, improves power supply by allowing power distribution between AC and DC. To smooth the power transmission between the AC and DC networks in the unit, a bidirectional hysteresis power transfer and a power harmonic filter in the microgrid can be used.

VII. OVERVIEW OF CONTROL ASPECT OF MICROGRIDS

Because of its benefits such as greater power sharing, enhanced system dynamics, and optimal management, hybrid AC/DC microgrid is gaining popularity. However, the complex structure makes modelling and stability analysis extremely difficult. The dynamic phasor model has been widely used in the simulation of AC microgrids in recent years. On the basis of the Fourier Transform, dynamic phasor converts sinusoidal values to constant numbers, making the modelling of AC microgrids considerably easier [55]. The authors created a hybrid model of a droop-controlled hybrid AC/DC microgrid using a dynamic phasor model on the AC side and a traditional state-space averaging model on the DC side. To study the influence of droop gains on the hybrid AC/DC microgrid, a small signal stability analysis is performed with the aid of the developed hybrid model. The authors discovered that higher droop gains cause the dominant eigenvalues on both the AC and DC sides to become unstable. As a result, the system stability margin is affected by the droop values chosen on both the AC and DC sides.

In the modelling and design of controllers, the traditional design technique documented in the literature considers the rated supercapacitor voltage. Due to self-discharge, the supercapacitor unit can discharge as low as 10% of its rated voltage. It has been discovered that using the traditional way of controller design can make the system unstable or cause ringing in the DC link voltage when the supercapacitor voltage is low. The design and stability analysis of a DC microgrid has been explained in [56]. The authors have used DC microgrid with battery-supercapacitor energy storage system under variable operating voltage of supercapacitor.

The divide between the DC and AC components of the grid is shrinking as more distributed generation with power electronics-based interfaces is used. Impedance-based analysis approaches are proven to be more potent than standard statespace-based analysis approaches in such inverter-dominated AC grids. Even traditional metrics and criteria for estimating the stability of generators and stronger networks are insufficient to properly reflect the dynamics of weaker, inverter-dominated networks. It follows that system impedances, which are routinely used to study DC systems, will also be useful in analysing grid-forming inverters in hybrid systems. The authors [57], [58] have detailed addressed an instance example employing traditional P-f/Q-V droop control that highlights the use of impedance-based analysis to evaluate the controller's influence on the inverter's input and output stability.

Because of the soft-starting technique, inhomogeneous initial values are common for practical microgrids. The input - output mappings error between the original system and the reduced-order system is significant when typical model order reduction procedures are used. To resolve this concern, the authors [59] offers a reduced-order aggregate model based on balanced truncation as a preparatory strategy for real-time modelling of large-scale converters in DC microgrids with inhomogeneous initial conditions. To begin, the non-leader multiagents idea is used to build a conventional linear time-invariant model with inhomogeneous initial conditions which make it simple to construct complicated system modelling using switched topology. In addition, the entire system is split into two parts: an unforced component with nontrivial initial circumstances, and a forced component with null initial circumstances. An aggregated strategy is presented in [59], which includes independent reducing component responses as well as merging lowering component responses. The error in the input-output mappings is decreased as a result of this.

Droop control is a good option for stand-alone power systems with several batteries since it allows inverters to communicate without interfering with each other [60], [61]. Small-signal instability occurs when the droop coefficients of batteries fluctuate with their SOC and charge/discharge mode. However, conventional impedance-based techniques can only examine the stability point of the droop coefficients, not the stability zone. The authors [61] provided a stability region analysis method based on droop coefficients. The authors discussed the charge/discharge SOC-based droop regulated battery, the P&Q controlled distributed generator, and the constant power load. The state matrix and return-ratio matrix are created. In addition, a new prohibited region criterion based on the return-ratio matrix was developed, which has lower conservatism than norm-based impedance criteria and partial forbidden area criteria. The Hurwitz identification problem using the equivalent return-ratio matrix was also focused with such a banned area criteria.

VIII. COMMERCIAL EXPLORATION

The integration of hybrid renewable energy into the microgrid system has generated electricity issues, such as load mixing, voltage volatility, differences in frequency, current stability, reliability and low energy use of each renewables source. Consequently, more equipment is needed to solve the resulting problem, such as a storage facility, converters and others. However, additional equipment would impact economic viability in terms of electricity costs, investment return, and other factors for the microgrid initiative. In order to ensure the cost efficiency and long-term sustainability of microgrid ventures, economic viability is critical. Therefore, the next subtopic of this section is reviewed in financial analysis.

A. TECHNICAL AND FINANCIAL ECONOMIC ANALYSIS

Technical and economic analyses are the most crucial part of the project feasibility study to ensure it can last long and worth investment. Technical analysis refers to all non-financial parameters such as electricity tariff, operational, and maintenance cost. Meanwhile, financial analysis refers to all financial parameters like interest payment, principle payment, tax, etc. Both technical and financial parameters need to amalgamate in cost modeling projects to determine the project's long-term sustainability.

Reference [62] suggested technological and economic viability in St. Martin, Bangladesh for the implementation of the microgrid. The feasibility review was carried out in two phases, pre- and post-feasibility studies. The HOMER tools have been used to evaluate the pre-feasibility of cargo production, meteorological data, resource evaluation, economic parameters, and techno economic simulation. After the results were obtained, there was a risk analysis post-feasibility study: sensitivity analysis and scene analysis to observe the main effect on the total expense of the device by a few variables.

The study of a scenario was conducted by analyzing the best case scenario, the worst case scenario and the proposed scenario analysis to determine the case scenario proposed [62]. The sensitivity or crucial factor analysis is, however, an instrument of the financial model used to assess the impact of the targeted variables dependent on variables other than input variables. In [62], four critical elements of sensitivity analysis were identified by researchers: diesel cost, wind speed, solar radiation and primary load, which affected positive energy costs and overall net current value in the first place. Reference [63] have set a tariff rate to analyze the percentage decrease in the capital cost of PV and wind sources as a sensitivity analysis.

In comparison, [64] are the initial steps in the economic review, assessing capital expenditures, costs for repair, maintenance and repairs on all facilities such as solar photovoltaic, wind turbines, batteries and conversion systems. The economic analyzes are then focused on gross Net Present Costs (NPCs), Levied energy costs (COE's) and microgrid operating costs. The authors carried out an economic study focused on the hybrid optimization of multi-electric green energy (HOMER) in the Sapra Village in Jharkhand (India) to carryout technical and economic analyses. To summarize, in the feasibility report of the microgrid project for more detail, the planned technological and economic analysis in [62] and [64] can be combined. Sensitivity and review of the scenarios can be carried out in [62] and [64] to study the microgrid project NPC and COE shift. The best way to make sure the project is viable and worth investing can then be created by research.

TABLE 5. Summary of economic research for a project of microgrids.

Analysis of economy	Explanation	Purpose	Ref.
Analysis of Life Cost	Capital costs, substitution costs, F&E costs, energy costs (COE), greenhouse gas pollution costs and energy demand costs	Maximize benefit, reduce the cost of investment	[68]
Environmental and financial viability	Pre-facilitating (load and demand approximation, etc.) and practicability afterwards (risk, sensitivity and consequence analysis)	Possibility of microgrid venture	[47]
Study of the technical economy	Return on investments, net current, domestic rates and risk analysis	Decision on financial feasibility of projects	[69]
Overall Cost of Energy (COE)	Capital costs, substitution costs, O&M costs on all appliances	Ensure financially viable investment in the project	[47]
MDS Tool	Incentives, taxes, incentives for renewables, allowance for reduced emissions, net metering and feed in tariff	Obtain optimum study of energy, financial viability and insecurity	[50]

B. ENTICEMENT AND INVENTIVENESS IN MICROGRID PROJECT

Today, every nation is setting up a green energy opportunity and programmes to promote the growth of renewables in its country. Therefore, an infrastructure entrepreneur is willing to deploy programmes focused on clean energy to finance them. Reference [65] have considered programmes by the Indian government as part of techno-economic study to deploy renewable energy, such as diesel reductions, the solar energy system, and the electrifying scheme of remote villages. Techno economic analysis was simulated using a non-linear quadratic programming approach that combined a concurrent sequential mixed disparity and equal rights restriction and estimated using simulation to assess the economic feasible of a hybrid solar thermal and wind power microgrid.

Reference [66] is also consideration in the performance review and planning of the MD Stool hybrid energy microgrid scheme of integrating income, taxation, tax subsidies such as clean energies, carbon reductions allowances, net metering, feed-in tariffs, requests response and grid supports. MD Stool is flexible in applying financial taxes or rules in each field and seeks to achieve optimum green energy mixes, conduct energy analyses, economic feasibility and an analysis of uncertainty.

C. ECONOMIC ANALYSIS RISK ASSESSMENT

Risk management is another concern to be found in investing in a microgrid project. Risk evaluation is recognized in project management as a hazard that affects the financial analysis of the project. Four crucial unknown variables are found in [67]: fuel price, foreign currency prices, energy demand and demand price power. The authors thus proposed to evaluate the impact of technological design decisions on the financial feasibility of the Microgrid Investment Project (MIP). This Stochastic Techno-Economic Microgrid Model (STEMM) is the basis. STEMM has two main components: technological and financial models for simulation purposes connected together. STEMM can also compute metrics that take risk and volatility into consideration, and can model tariffs that change over time in real time. The technological model has been integrated into the financial model with the income-generating demand, fuel usage, generator runtimes, battery power fading and charge shed. The STEMM financial model simulates the cash flow of a monthly settlement, covering the expense of money, running costs, sales, income tax, and interest payments.

IX. FUTURE WORK

Any more analysis needs to be looked at in the following subtopic in order to create a viable management plan for hybrid biomass-solar photovoltaic-wind turbine micro-grid.

A. POWER QUALITY

Some recent effort has been made to study the power quality in voltage, frequency, and power flow control in hybrid solar photovoltaic-wind turbine microgrid. However, there is no further study of power quality for hybrids biomass-solar photovoltaic-wind turbine microgrid. Power quality is significant to ensure reliability and efficiency operation of hybrid biomass-solar photovoltaic-wind turbine microgrid. Thus, voltage control. Therefore, the voltage, frequency, and power flow control for hybrid biomass- solar photovoltaic-wind turbines need more research in the future to improve system reliability.

B. REAL-TIME TESTING

Majority of previous works on hybrid biomass-solar photovoltaic-wind turbine microgrid are based on simulation. The real-time testing of these microgrids needs to be done before actual deployment to avoid any encountered problem before deployment. Furthermore, a new problem that never happened in simulation also can be arisen when real-time testing is done. Thus, it is important to do real-time testing to overcome the microgrid deployment issued that can substitute the conventional grid in the future.

C. COMPREHENSIVE ECONOMIC ANALYSIS

Previously, the researcher has done many kinds of research on hybrid biomass-solar photovoltaic-wind turbine microgrid economic analysis. However, economic analysis mostly only focuses on cost analysis to minimize the cost of energy. The overall project analysis of microgrid is shown in Table 5. To determine the microgrids feasibility, a comprehensive economic analysis needs to be done to determine whether it is viable to implement the microgrid in selected areas. A comprehensive economic analysis can be done by executing the Techno-Financial Model (TFM) in the microgrid project. TFM considers the technical model, financial model, risk assessment, discount, operational and maintenance cost, construction budget, debt servicing and dividend schedule, incentive, and microgrid project initiative.

As a result, the Internal Rate of Return (IRR), Return of Investment (ROI), payback period, and NPV will be calculated to determine the microgrid project's feasibility.

X. CONCLUSION

This research article provides information on hybrid micro grid for renewable energy in the grid, off-grid, control strategies and economics. Solar photovoltaic and wind energy are usually combined in a hybrid system, which essentially support each other. This article reviews the design of green hybrid energy, analyzing the required architecture for hybrid biomass applications – microgrid solar photovoltaic, wind turbines. However, it becomes impossible to use this concept of renewable energy in a micro-grid because of the intermittent temperature variability of its facilities. The research thus looks at the management strategy for the photovoltaic, wind turbine, biomass and solar microgrid, which is grid- and off-grid-connected. The voltage control and frequency control are included. Based on the evaluation, the reliability of voltage, frequency stability and control stability should be monitored using a consensus protocol. The final section of the research paper addresses the economic overview of the Microgrids framework including cost analysis, technological and financial analysis, risk evaluation, and microgrid initiative. This paper also highlights the incentives to reduce costs and to examine the possibility of integration into the microgrid system of hybrid renewable energy. The possible factors for future options are power quality, real-time monitoring and a thorough economic analysis in the hybrid biomass-solar photovoltaic-wind turbine microgrid.

ACKNOWLEDGMENT

The authors would like to thank the Department of Electrical Engineering, IIT (Indian School of Mines) Dhanbad, India, for providing the laboratory related facilities to accomplish the research work in time. The author Shiv Prakash Bihari would like to thank Prof. R. K. Saket, Prof. L. D. Arya, and Prof. D. P. Kothari for the technical expertise provided.

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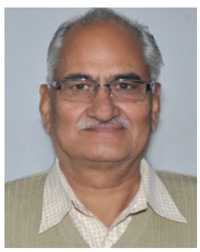

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