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Enhancement of Grid Stability in Hybrid AC/DC Microgrids with Coordinated Control Strategies

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ABSTRACT

This study presents a hybrid alternating current/direct current microgrid to minimize grid conversions. Hybrid grid multi-directional converters interlink AC and DC networks. DC and AC networks interconnect sources and loads. Energy storage systems may use either direct current (DC) or alternating current (AC) networks. Employ connected or hybrid grids. Coordination control systems enable the transmission of alternating and direct current energy while maintaining stable operation under fluctuating generation and load situations. Wind, sun radiation, temperature, and load fluctuate abruptly. Essential hybrid grid simulation with MATLAB Simulink. The simulation illustrates that coordination control may preserve grid stability across different operating modes.

KEYWORDS: *Boost Converter; Bidirectional AC/DC Converter; AC Microgrid; DC Microgrid; AC/DC Microgrid; DFIG – Doubly Fed Induction Generator.*

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I. INTRODUCTION

Microgrids are integrating with bigger power networks via renewable energy sources in response to escalating environmental and energy challenges. Electricity is generated by AC/DC microgrids. [1, 2]. AC microgrids are used in power networks because of their user-friendliness. The contemporary culture and alternative direct current power sources, such as solar energy, have contributed to the increasing popularity of direct current microgrids. Data centers, air conditioning systems, and energy conversion devices are all being integrated into AC grids [3, 4]. In AC microgrids, DC apparatus and renewable energy sources may exhibit superior performance and reduced costs. AC and DC electrical devices will coexist temporarily, since both the primary power source and the AC microgrid use alternating current. Power losses, control issues, and harmonic currents may be alleviated in AC or DC microgrids by eliminating superfluous conversions. Microgrids may use either DC or AC power sources, depending upon availability. Due to its benefits compared to just DC or AC microgrids [6, 7], hybrid AC/DC microgrids are becoming popular worldwide. Hybrid AC/DC microgrids use AC/DC converters and microgrids to provide bidirectional power flow [8, 9]. A bidirectional AC/DC converter regulates the electricity flow inside the microgrid. Both are advantageous for hybrid AC/DC microgrids. DC and AC electrical devices linked to a hybrid AC/DC microgrid may receive power from several sources without requiring any conversions. Minimize energy waste and enhance the efficacy of the power conversion process. Static transfer switches facilitate the connection and disconnection of the hybrid AC/DC microgrid from the main grid. Increased regulation is necessary for AC/DC microgrid hybrids [10, 11]. Microgrids that integrate alternating current (AC) and direct current (DC) power sources are referred to as hybrid AC/DC microgrids. The AC microgrids interconnect the DC microgrids inside a hybrid system. It may be used both off-grid and on-grid. The potential for AC microgrids interconnected with the broader grid is limitless [12]. Bidirectional AC/DC converters and batteries may be used to regulate DC bus voltage and achieve power equilibrium in AC and DC microgrids. U-Q and PQ regulate energy transfer in both directions of the AC/DC converter. When the primary converter requires power quality control, continuous power augments the AC microgrid with photovoltaic energy. U-Q management optimizes DC photovoltaic use by directing surplus photovoltaic energy to the AC microgrid. The AC/DC converter operates bidirectionally, facilitating the transition between U-Q and PQ modes. In island mode, in the absence of a grid, batteries and a bidirectional AC/DC converter are used to maintain balance between supply and demand. The AC/DC converter controls the voltage and frequency of the AC bus. Battery nodes may be used to balance subgrids of alternating current and direct current. Model and architecture for AC/DC microgrid simulations. This article provides a brief overview of the submodule controllers used in a hybrid AC/DC microgrid. Coordination and control systems are rigorously tested in a virtual environment.

II. SYSTEM CONCEPTUALIZATION AND DEVELOPMENT

A. Microgrid with an AC/DC hybrid power supply

Power flow and AC/DC systems are shown in Figure 1 for a simple hybrid AC/DC microgrid. This is a 45 kW DFIG wind turbine, which stands for "double fed induction generator" and three-phase alternating current (AC) loads are directly connected to the AC bus through a back-to-back AC/DC/AC converter [13]. DC sub-microgrid is a copy of DC electrical devices, consisting of 228 KW of PV arrays (15 parallel and 10 series), 400 Ah of battery storage, and direct-connected variable DC loads. Power in AC and DC sub-microgrids is controlled via bidirectional AC/DC converters. The PCC enables either grid-connected or island-based operation of the hybrid microgrid. An isolated hybrid microgrid is the result of an opened breaker. The hybrid microgrid is connected when the breaker is closed.

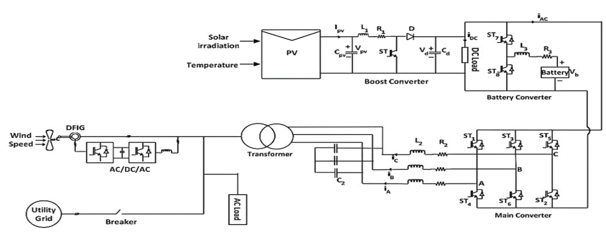

Figure 1: Representation of proposed hybrid grid

B. Grid-Connected Mode

The utility grid balances electricity, eliminating the battery converter. The primary converter reduces the voltage drop across the dc bus and the amount of reactive power lost throughout the process. DC to AC conversion occurs when DC supply surpass DC loads. Pumping occurs when the converter's power output is less than the dc side's load. Hybrids feed the grid. Utility manages.

C. Isolated Mode

Islanding disconnects the hybrid grid from the utility grid. Battery balances power and voltage. Battery or boost converter maintain DC bus voltage, depending on circumstances. The primary converter supplies continuous, high-quality alternating current bus voltage.

D. The PV panel's modeling

PV systems are made up of modules connected by PV panels in series or parallel. PV panels are diode-powered current sources. Equation (1) shows PV panel mathematics, whereas Figure 2 shows a PV panel equivalent circuit model [13].

$$I_L = I_{ph} - I_s\left(e^{\frac{q(V+IR_s)}{AKT}} - 1\right) - \frac{V+IR_s}{R_{sh}} \quad (1)$$

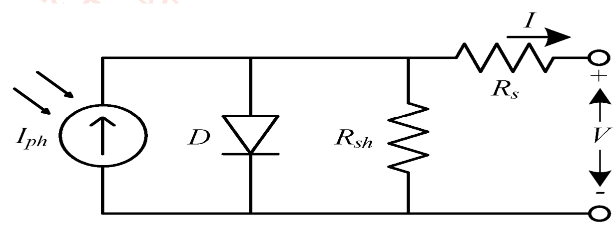

Figure 2: PV panel single-diode equivalent circuit

E. The battery's modeling

The battery is essential to distributed generation as an energy storage device, but its internal characteristics interact non-linearly. Equations (2) and (3) reflect the battery model's voltage and SOC [14].

$$V_b = V_0 + R_b \cdot i_b - K\frac{Q}{\int i_b dt} + A \cdot exp\left(B\int i_b dt\right) \quad (2)$$

$$SOC = 100\left(1 + \frac{\int i_b dt}{Q}\right) \quad (3)$$

F. The WT generator's modelling

The WT's mechanical power output is as follows:

$$P_m = 0.5\rho A C_p(\lambda,\beta)V_\omega^3 \quad (4)$$

where (ρ) is air density, (A) is turbine swept area, V_ω is wind speed, and C_p (λ, β) is the power coefficient, which is the function of tip speed ratio (λ) and blade pitch angle (β).

III. CONTROL APPROACHES

A. PV array control scheme

Temperature and irradiance impact PV system power output. MPPT mode on the boost converter maximizes PV array performance. MPPT control algorithms maintain PV array efficiency regardless of irradiance and temperature. Simple MPPT methods like P&O [15] are popular. Figure 3 shows the P&O algorithm.

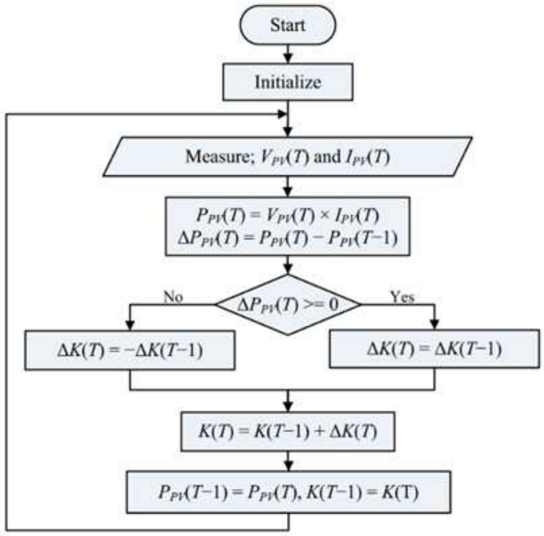

Figure 3: P&O Algorithm

Figure 4 shows how the P&O approach modulates the boost converter's duty cycle to monitor PV array MPP. MPPT improves solar generator energy supply. This process used boost converter control. The MPPT algorithm generates the ideal reference voltage Vm by detecting the PV array's current voltage Vpv, and the PI regulator reduces the error signal between Vpv and Vm. The PWM generator provides the switch pulse signal to activate MPPT [6].

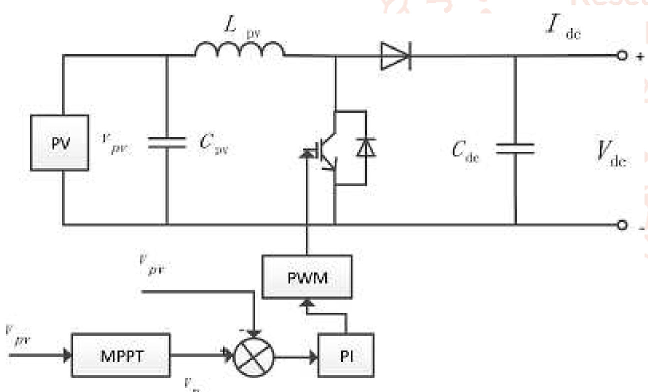

Figure 4: PV array strategy

B. Battery management approach

Independent and grid-connected energy storage configurations are necessary for this research. The two-way DC/DC converter shown in Figure 5 is capable of maintaining a constant voltage on the DC bus while the battery is being charged or discharged. The voltage and current of the DC bus are both under the control of the bidirectional DC/DC converter higher than the DC bus's reference voltage [13]. Switching from S1 to S2 causes the converter to operate as a buck circuit, allowing the hybrid microgrid to charge the battery. The converter becomes a boost circuit and the battery is discharged to power the loads when the DC bus voltage VDC drops below the reference voltage VDC, activating IGBT S1 and deactivating S2.

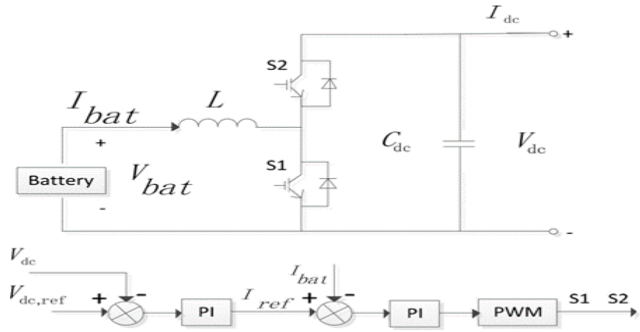

Figure 5: Battery charge and discharge control scheme

C. DFIG's control approach

Control of wind power plants often include management of both the generator's WT and DFIG's back-to-back AC/DC/AC converters. Converting from one kind of AC current to another, in series. The DC link voltage is regulated by the grid-side converter, while active and reactive power on the rotor side is managed by the rotor-side converter. The rules for DFIG compliance are laid forth in [9].

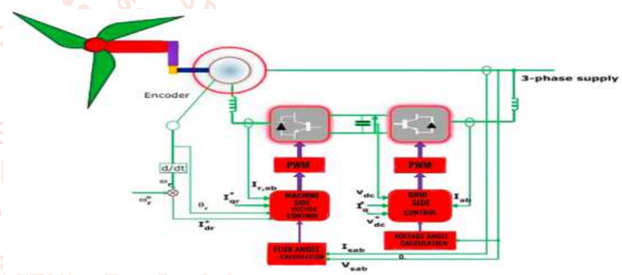

Figure 6: DFIG - Doubly-Fed Induction Generator

D. The bidirectional AC/DC converter's control scheme

One of the most important parts of a hybrid microgrid is the main converter, often known as a bidirectional AC/DC converter. Maintaining consistent bus voltages and distributing electricity evenly across AC and DC microgrids both contribute to system reliability.

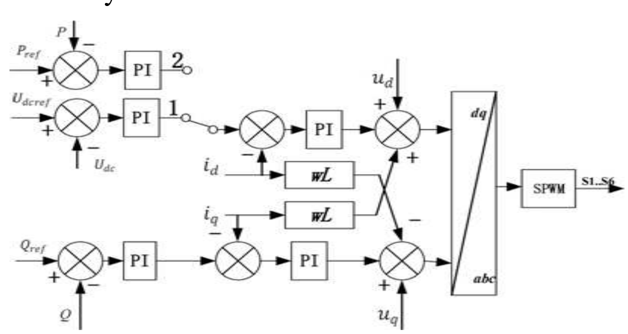

Figure 7: Control method for grid-connected bidirectional AC/DC converters

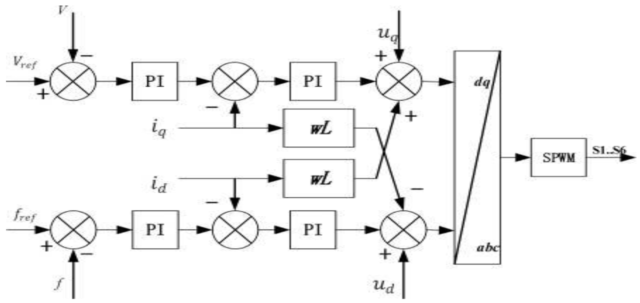

Figure 8: Control method for an islanded mode bidirectional AC/DC converter

IV. SIMULATION RESULTS AND ANALYSIS

MATLAB/SIMULINK models hybrid microgrids. The method joins the grid. The hybrid microgrid, doubly fed induction generator, and solar system are being tested. Hybrid microgrid studies involve solar irradiance, cell temperature, and wind speed. Performance analysis using MATLAB simulations.

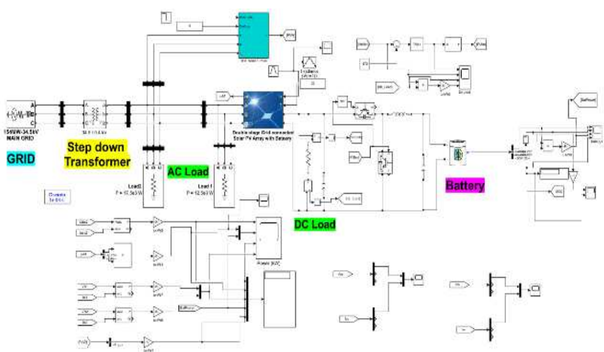

Figure 9: Simulink Model of Hybrid AC/DC Microgrid

A. PV array simulation Figures (10) and (11) show P-V characteristics with sun irradiation. The figures show that the PV cell's output power depends on its terminal operating voltage, temperature, and solar irradiation, demonstrating its nonlinearity.

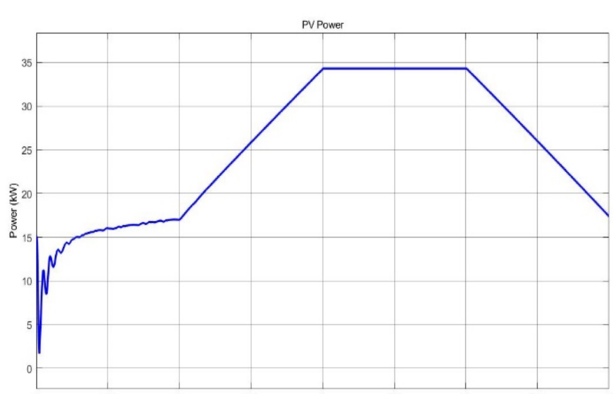

Figure 10: Photovoltaic (PV) Power Vs Time In (S)

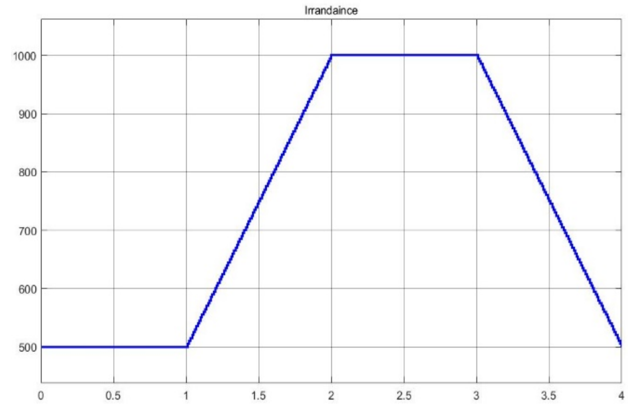

Figure 11: Irradiance Vs Time In (S)

B. Results of a Doubly Fed Induction Generator (DFIG) Simulation with Grid Power, Solar PV, and Battery in Relation to AC Loads

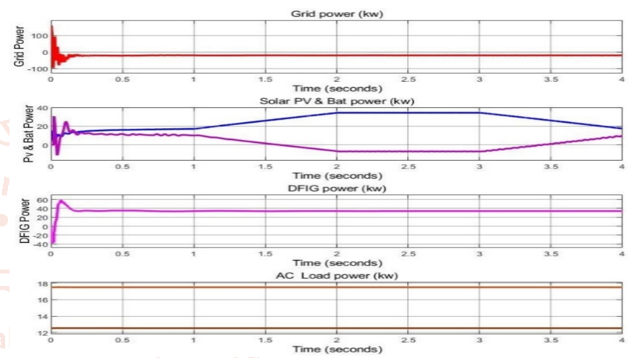

Figure 12: Grid Power (Kw), Solar PV & Battery Power (Kw), DFIG Power (Kw) & Ac Load Power (Kw) Vs Time In (S)

C. Battery Charging and Discharging Simulation Results with SOC%

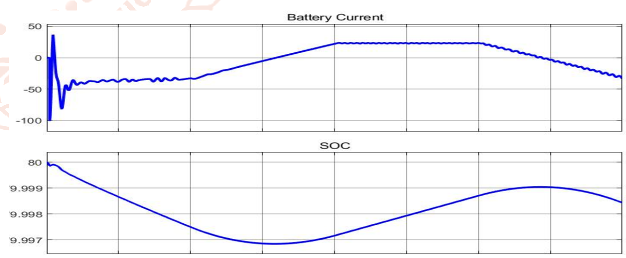

Figure 13: Battery Current & Soc Vs Time In (S)

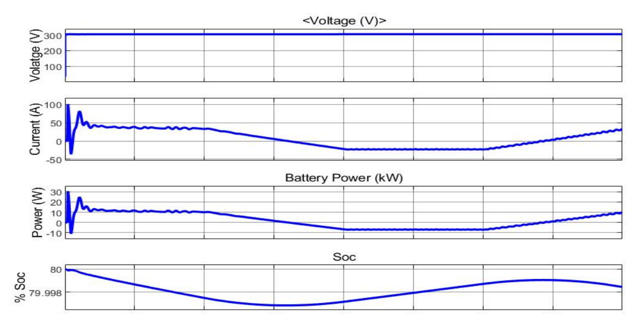

Figure 14: Battery - Current, Voltage, Power (Kw) & Soc % Vs Time In (S)

D. Simulation Results Correspond to DC Load

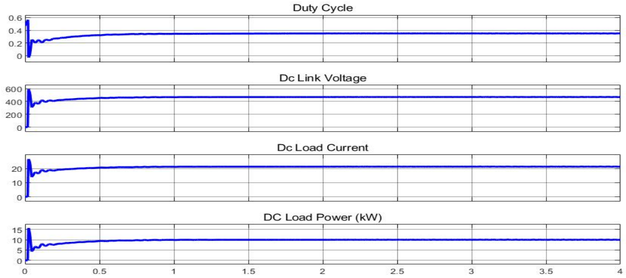

Figure 15: Duty Cycle, Dc Link Voltage, Dc Load Current & Dc Load Power (Kw) Vs Time In (S)

CONCLUSION

This research introduces a hybrid microgrid that integrates AC and DC systems. The system operates reliably across various resource and load circumstances, owing to models and coordination control methods for all converters. The coordinated control strategies are validated using MATLAB/Simulink. Diverse control methodologies have been developed to optimize power extraction from direct current (DC) and alternating current (AC) sources, as well as to regulate power interchange across grids. Examining resource conditions and load capacity substantiates control approaches. The hybrid grid may function in either a grid-connected or isolated mode, according on the modeling. The voltages of alternating current and direct current buses may be maintained at a stable level despite fluctuations in operating conditions or load capacity.

REFERENCES

[1] Feng Gao; Xiaohui Wang; Peihao Yang; Shuichao Kou; Mengyao Sun "Research and Simulation of Hybrid AC/DC Microgrid" IEEE 2020 4th International Conference on HVDC (HVDC).

[2] Lingfeng Kou; Xiaoyun Qu; Geng Niu; Baodi Ding "The Design Method of AC-DC Microgrid Based on Smart Energy Station" IEEE 2020 IEEE 4th Conference on Energy Internet and Energy System Integration (EI2).

[3] Heng Du; Xuemeng Zhang; Qiuye Sun; Dazhong Ma "Power Management Strategy of AC-DC Hybrid Microgrid in Island Mode" IEEE 2019 Chinese Control and Decision Conference (CCDC).

[4] Pengfei Tu; Shuhan Yao; Peng Wang; Lalit Goel "Hierarchical Reliability Modelling of an Islanded Hybrid AC/DC Microgrid" 2018 IEEE International Conference on Probabilistic Methods Applied to Power Systems (PMAPS).

[5] Hao Zheng; Hongwei Ma; Kaiqi Ma; Zhiqian Bo "Modeling and analysis of the AC/DC hybrid micro-grid with bidirectional power flow controller" IEEE 2017 China International Electrical and Energy Conference (CIEEC).

[6] A. A. Eajal; Mohamed A. Abdelwahed; E. F. El-Saadany; Kumaraswamy Ponnambalam "A Unified Approach to the Power Flow Analysis of AC/DC Hybrid Microgrids" IEEE Transactions on Sustainable Energy (Volume: 7, Issue: 3, July 2016).

[7] Wenjiao Guo; Xiaoqing Han; Chunguang Ren; Peng Wang "The control method of bidirectional AC/DC converter with unbalanced voltage in hybrid micro-grid" 2015 IEEE 10th Conference on Industrial Electronics and Applications (ICIEA).

[8] Rahul Anand Kaushik; N. M. Pindoriya "Power flow control of hybrid AC-DC microgrid using master-slave technique" 2014 IEEE Conference on Energy Conversion (CENCON).

[9] Nabil Qachchachi; Hassane Mahmoudi; Abdennebi El Hasnaoui "Optimal power flow for a hybrid AC/DC microgrid" IEEE 2014 International Renewable and Sustainable Energy Conference (IRSEC).

[10] A. Mohamed; Sri Raju Bushanam Vanteddu; O. Mohammed "Protection of bi-directional AC-DC/DC-AC converter in hybrid AC/DC microgrids" 2012 Proceedings of IEEE Southeast con.

[11] Poh Chiang Loh, Ding Li, and Frede Blaabjerg, "Autonomous Control of Interlinking Converters in Hybrid AC-DC Microgrid with Energy Storages," in IEEE Energy Conversion Congress and Exposition (ECCE), pp. 652-658, 2011.

[12] Bo Dong, Yongdong Li, Zhixue Zheng, Lie Xu "Control Strategies of Microgrid with Hybrid DC and AC Buses," in Power Electronics and Applications, EPE'11, 14thEuropean Conf., pp. 1-8,2011.

[13] Xiong Liu, Peng Wang, and Poh Chiang Loh, "A Hybrid AC/DC Microgrid and Its Coordination Control," IEEE Trans. Smart Grid, vol. 2, no. 2, pp. 278-286 June.2011

[14] MeiShan Ngan, Chee Wei Tan, "A Study of Maximum Power Point Tracking Algorithms for Stand-alone Photovoltaic Systems," in IEEE Applied Power electronics Colloquium (IAPEC), pp. 22-27, 2011.

[15] Chi Jin, Poh Chiang Loh, Peng Wang, Yang Mi, and Frede Blaabjerg, "Autonomous Operation of Hybrid AC-DC Microgrids," in IEEE Int. Conf. Sustainable Energy Technologies, pp. 1-7, 2010.