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INTEGRATION OF COMBINED HYBRID ENERGY STORAGE SYSTEM WITH MULTI-SOURCE CONVERTER FOR DC MICROGRID APPLICATIONS

[1]M.Rajyalakshmi,[2]J.Nageswara Rao,[3]T.Lingaiah,[4]Kanaparthi Renukadevi
[1,2,3]Associate Professor,[4]Student
Department of EEE
G V R & S College of Engineering & Technology,Guntur,AP

ABSTRACT: An efficient energy management system for a photo voltaic-wind and hybrid energy storage (HES) integrated multi source converter configuration for DC micro grid is proposed in this paper**.** The Renewable energy sources like photovoltaic-wind energy conversions systems are developed and used for integrating the multi-source converter with hybrid storage converter. The use of Super capacitor-Battery based HES are interfaced to handle the power fluctuations and sudden load disturbances. The super capacitors contain high frequency fluctuations and rapid charging of battery storage and increases the life time of battery storage and reduces the sizing of storage unit. The maximum power point energy storage is based on charging and discharging of power availability. The main aspects of proposed configuration are: (i). less number of switches, (ii). voltage boosting, voltage regulation of super capacitor and power sharing among battery are of same characteristics, (iii). simple control structure with a reduced number of sensors are used. This study will a new multi-source and hybrid energy storage combined converter for micro grid applications. The designing of the proposed configuration and control structure are simulated through MATLAB simulations and experimental validations.

Keywords:microgrid interconnection; power fluctuation mitigation; energy storage capacity optimization.

1. INTRODUCTION

Photovoltaic (PV) solar power has been one of the fastest-growing forms of renewable energy being integrated into distribution grids in the past decade [1]. The output power of PV panels is dependent on environmental conditions such as irradiance and temperature and is therefore intermittent and variable in nature. With increasing level of PV integration, the safety and reliability of the distribution grid may degrade. The power fluctuations of PV can have a significant impact distribution system operation and planning. Short-term PV power fluctuation may cause voltage quality degradation and overvoltage problems. Frequent occurrences of overvoltage can accelerate the switching actions of voltage control and regulation devices such as load tap changers (LTCs), line voltage regulators (VRs), and capacitor banks, which may lead to an increase in equipment wear or further aggravation of problems that affect more equipment and customers [2]. As for system planning, long-term PV fluctuation may affect load forecasting and require a redesign of the structure of the distribution grid. For example, more voltage regulators and larger size wires will be needed to handle fluctuations [3].

To improve the penetration level of PV power in the distribution grid, PV power fluctuation mitigation techniques have been investigated. Existing research works on this topic can be generally classified into the following three categories:

- Active power curtailment: When the power fluctuation is large enough to worsen the grid voltage, the operation mode of the renewable energy source (wind or PV solar) should switch from maximum power point tracking (MPPT) to constant active power control [4].
- Demand response of local loads: Assuming the local loads are controllable and PV

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power forecasting is adopted, power fluctuation can be smoothed by adjusting the local loads curve to make up for the PV power curve [5].

- Microgrid integration with energy storage system (ESS): Solar PV, local loads, and ESS can be integrated into a microgrid, where the net power fluctuation coming from PV panels and loads can be compensated by the ESSs before affecting the upper-level grid [6,7,8].

2. Literature survey

Among various methods, active power curtailment is achieved by reducing PV utilization. This is against the overall goal of PV penetration improvement. Local load demand control requires the loads to have a certain level of intelligence, which may not be feasible in practical scenarios. In comparison, the microgrid integration scheme with ESS is free of these limitations and is a more favorable approach that has gained increasing popularity [9].

Microgrid integration with ESS became an attractive option for distributed generation (DG) lately [10]. AC microgrid is built by clustering distributed sources, ESS and loads. These microgrids can be thought of as controllable sources or loads, designed to exchange power with the upper-level distribution grid through a transformer located at the point of common coupling (PCC) [11]. Through a suitable power control strategy of ESS, the net power fluctuation of microgrids can be curbed [12,13,14,15]. However, considering the high unit cost of ESS, the existing solution is still not sufficiently economically favorable for compensating enormous power fluctuations in high PV penetration situations [16].

Recently, with the aim to facilitate the connection of various AC and DC renewable sources and loads to power systems, the scheme of multi-microgrid interconnection was proposed to link microgrids through power converters. The scheme also helps expand capacity and improve power supply reliability of microgrids. A multi-layer architecture for voltage and frequency control in AC multi-microgrids was proposed in Reference [17], where a coordinated operation in different microgrid control modes was achieved. In References [18,19], an AC/DC multi-microgrid structure was introduced, and its decentralized multi-time scale power control and energy management strategy were studied. All these recent works on multi-microgrid schemes mainly focused on the coordinating operation and control of microgrids via the interconnecting power converters, while the design, configuration, and control of ESS and interconnecting converters were largely left undiscussed. In fact, with the interconnected microgrid scheme in place, the capacity of the system ESS used for power fluctuation mitigation can be optimized, which requires comprehensive study and analysis.

By introducing electrical ties and energy exchanges among AC microgrids, a novel flexible multi-microgrid interconnection scheme is proposed in this work to provide a better solution for mitigating power fluctuation. The key idea behind developing the scheme is based upon the fact that microgrids contain various types of DGs and loads and have different network structures and application scenarios. Their net power curves possess clear distinctions as a result [20].

3. Proposed model

Intermittent energy sources and an imbalance in energy resources are the two main reasons to establish a hybrid energy supply system. Because the wind does not constantly blow and the sun does not always shine, using a single source is not a wise choice.A battery-powered device that mixes wind and solar energy can be a far more dependable and useful power source. The stored energy in the batteries can power the load even when there is no wind or sunlight. In order to build systems with the lowest cost and highest reliability, hybrid systems are frequently used. Due to their high price, solar

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PV cells are less appropriate for systems with higher capacities. Here, wind turbines are useful because of their cheaper cost when compared to PV cells, which is also one of their key advantages. A battery system is needed to store the solar and wind energy produced during the day. An added benefit of wind at night is that it enhances the systems.Wind power is a renewable energy source. Wind power is transformed into electric power using wind turbines. The turbine's internal electric generator transforms mechanical energy into electrical energy. There are wind turbine systems ranging from 50W to 3–4 MW. The wind velocity acting on the turbine determines how much energy is produced by wind turbines. In rural locations, wind power can meet both the supply and the demand for electricity. It is used to power a windmill, which in turn powers an electricity-generating wind generator or wind turbine.Figure 1 shows the Proposed model of Combined Hybrid Energy Storage System with Multi-source Converter Arrangement for the Application of DC Micro-grid.

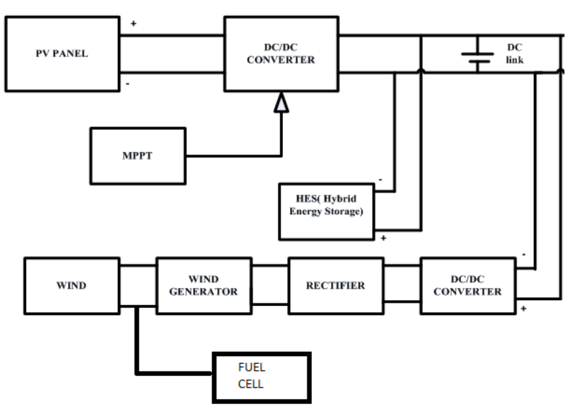

Figure 1. Block diagram of proposed model

3.1 PERTURB AND OBSERVATION (P&O) MPPT CONTROLLER

This controller offers a solar tracker for the stand-alone solar photovoltaic system and a modified Perturb and Observe (P&O) algorithm. The proposed algorithm limits the search area of the power curve to 10% and starts to interrupt and monitor the search area. The proposed P&O algorithm was simulated by MATLAB/Simulink. The solar tracker ensures that maximum radiation in the solar module is consistent throughout the day. Containing the algorithm's search area reduced the time to respond to changing weather conditions, thus reducing steady state oscillations in the MPP. The integration of the solar tracker and the improved P&O MPPT algorithm ensured better load quality, better conditioning of power. The system was experimentally controlled and the results confirmed the effectiveness of the P&O algorithm. The MPPT control extracts maximum power from the PV panels for good temperature and irradiation efficiency change. The P&O algorithm is well-known and skilled in the practice of this is an algorithm based on system perturbation. Results on PV output panel are achieved by applying different increments or decreases in the duties cycle. A small increase disrupts the working voltage of the PV module and the resulting power (after P) change is observed.

$$\Delta P = \frac{dP}{dV_{pv}}(x) = \frac{P(x) - P(x-1)}{V_{pv}(x) - V_{pv}(x-1)}$$

If the path moves toward MPP, the voltage should be extended, and if the voltage is $\Delta P < 0$, the path will move from MPP. The current and previous computed power represent P(x) and P(x-1), and the $V_{pv}(x)$ and $V_{pv}(x-1)$, respectively the present and previous PV voltage.In the next disturbance cycle, the reverse disturbance path is required. Repeated and working cycles for process feeding the DC-DC boost converter are generated.

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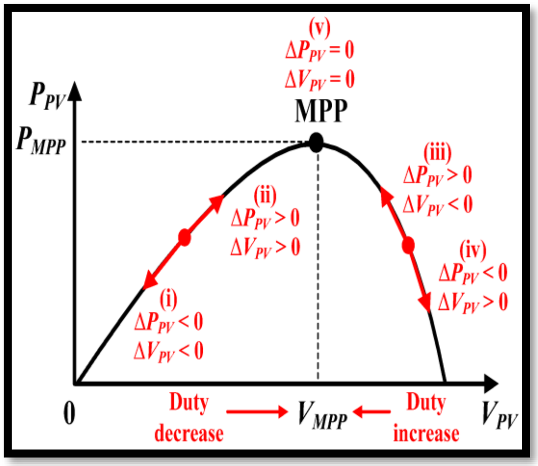

Figure 2. P & O MPPT Curve

Figure 2 diagram is the algorithm which is particularly suitable under constant or slow atmospheric conditions. Diagram for perturb and observation of MPPT algorithm

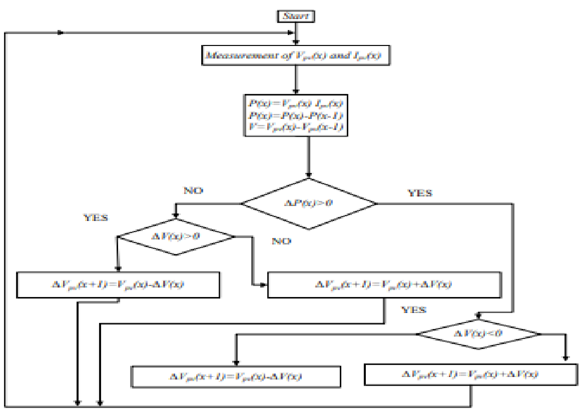

Figure 3. P&O MPPT Algorithm

3.2 EQUIVALENT CIRCUIT DIAGRAM OF BUCK-BOOST CONVERTER:

This type of converter nowadays is mainly used in electric vehicles. It is also called a Half-Bridge DC-DC converter. When the Buck and the boost converters are connected in anti-parallel across each other with the resulting circuit is primarily having the same structure as the basic Boost and Buck structure but with the combined feature of bidirectional power flow is called Bi directional dc-dc converter. It works in both directions.

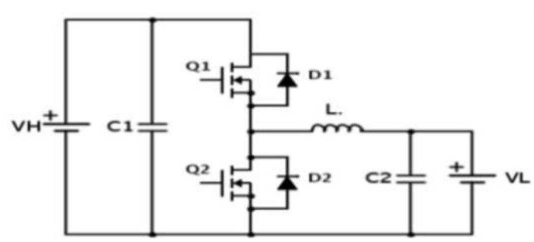

Figure 4. Diagram of DC-DC Boost converter

Figure 4 circuit can work in buck or boost mode depending on the switching of the IGBTs Q1 and Q2. The switches Q1 or Q2 in sequence with the anti-parallel diodes D1 or D2 (acting as a freewheeling diode) respectively, which makes the circuit step up or step down the voltage connected across them. The bidirectional operation of the above circuit can be described in the below two modes as follows:

Mode 1 (Boost Mode): In this mode switch Q2 and diode D1 begin into conduction depending on the duty cycle whereas the switch Q1 and diode D2 are off all the time. This mode can moreover be divided into two intervals depending on the conduction on the switch Q1 and diode D2.

Interval 1 (Q2-on, D2-off; Q1-off, D2-Off): In this mode Q2 is on and hence can be examined to be short-circuited, hence the lower voltage battery charges the inductor and the inductor current goes on rising till not the gate pulse is separated from the Q2. Also, since the diode D1 is reversed biased in this mode and the switch Q1 is off, no current flows into the switch Q1.

Interval 2 (Q1-off, D1-off; Q2-off, D2-on): In this mode, Q2 and Q1 both are off and therefore can be considered to be opened circuited. Now since the current flowing into the inductor cannot change immediately, the polarity of the voltage across it reverses and hence it starts acting in series with the input voltage. Therefore, the diode D1 is forward biased and so the inductor current charges the output capacitor C2 to a greater voltage. Therefore, the output voltage boosts up.

Mode 2 (Buck Mode): In this mode switch Q1 and diode D2 begin into conduction depending on the duty cycle whereas the switch Q2 and diode D1 are off all the time. This mode can moreover be divided into two intervals depending on the conduction on the switch Q2 and diode D1.

Interval 1 (Q2-on, D2-off; Q1-off, D2-Off): In this mode, Q1 is on and Q2 is off. The greater voltage battery will charge the inductor and the o/p capacitor will get charged by battery.

Interval 2 (Q1-off, D1-off; Q2-off, D2-on): In this mode, Q2 and Q1 both are off. Again, as the inductor current cannot change instantaneously, it gets discharged via the freewheeling diode D2. The voltage across the load is stepped down as correlated to the input voltage.

A comparison between the features of the non-isolated bidirectional topologies have been explained as during step-up mode, in the buck-boost bidirectional converter the RMS value of the current in the inductor and the power switches is greater by an amount equivalent to the output current as compared to the buck-boost cascade bidirectional converter. Furthermore, the capacitor RMS current also excels in the former case by an amount of the 1/3rd of the output current. Hence in the bidirectional buck-boost converter the power switches, inductor, and the capacitor work under more thermal and electrical stresses as compared to the buck-boost cascade converter following in greater power loss and also creating the saturation of the inductor core. Also, as the stress on the MOSFET and the diode is higher, the buck-boost bidirectional converter needs power devices with larger device ratings. Higher RMS currents also result in greater conduction losses and thus reducing the overall efficiency of the buck-boost bidirectional converter.

3.3. Fuel cell

A central control system is created to run the system with the least amount of operational expense. In order to achieve this, a hybrid system model is developed, in which both the features of the fuel cell vehicles and their travel patterns are taken into account. The system's operating expenses are calculated while taking into account the degree of uncertainty in the load prediction and the production of renewable energy. An effective min-max model predictive control scheme is created, and a case study is then used to demonstrate how well the designed system performs.

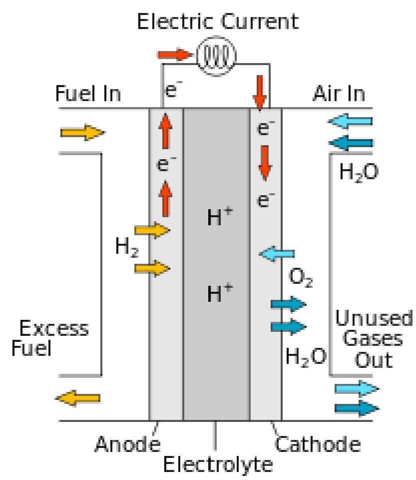

Figure 5. Fuel cell

An apparatus that transforms chemical potential energy (energy held in molecular bonds) into electrical energy is a fuel cell. Fuel cells resemble batteries in many ways. The reaction takes place between two electrodes, and an electrolyte transports the charged particles between the electrodes. Hydrogen is required for a fuel cell to function. At the anode, hydrogen enters the fuel cell. The hydrogen molecules have their electrons removed by a chemical reaction, which causes the atoms to ionise and create H +. To create a current that can perform work, the electrons go via wires. The oxygen normally comes from the air and enters at the cathode. The electrons that have finished their circuit are picked up by oxygen.

Here this Fuel cells is connected to the overall system as an extension for the model, after connecting the fuel cells to the Simulink model, the system gets operated with exact outputs compare to

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previous outputs.The model gets operated and outputs will be same as previous outputs. The Simulink model with Fuel cells connected to the previous model as an extension.

4. Results and discussions

The Simulink model consists of four modes of operations with some of conditions in multi-port converter.Here, P&), MPPT technique is used for extracting maximum power to the PV Panel, from load side given some command signals means initially it off from 0 to 2 from 2 to 4 going to connect with simulation, from 4 to 6 going to dis-connect the simulation, after 6 going to connect with simulation.

Values for Simulink model
1.solar- voltage- 17
current- 7.06
2.wind -current- 6.46
voltage- 14.67
3.wind speed - 12m/s
4.Pitch angle - 0
5.sample time- 10
6.Rotational speed generator- 10
7.frequency- 60HZ
stator phase resistance- 2.87ohms
8.No of phases- 3
9.Flux linkagae- 0.17

Table 1. Simu link model values

So, we can add the laod based of this logic.By Using PV means need to measure the PV voltage &current, it's going to process via MPPT then it connects to the PI controller & generate the gating signals. This Signals given to the switches S1, S2. Parallelly wind energy system also the signal given to the switches S4.

CONDITION:1 When PV and Wind OFF: Without Solar, Wind i.e. (solar-0, wind-0), here the PV and Wind will not consider, the system will operate with battery & super-capacitor and also can be change the load for every 2sec and then need to check the response of the voltage across the load, current in battery and super-capacitor. It contains some of the operations like, Voltage across the load, Inductor current of the converter, Super-Capacitor & Battery Currents (upper-battery, lower-super-capacitor, Load receiving current from the battery after 2sec load will be added, again after 4sec the load gets disconnects.

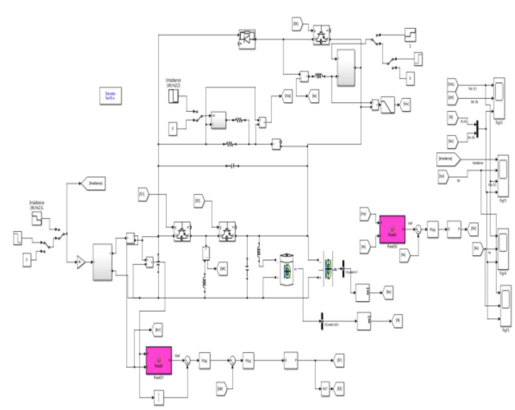

Figure 6. Simulink model

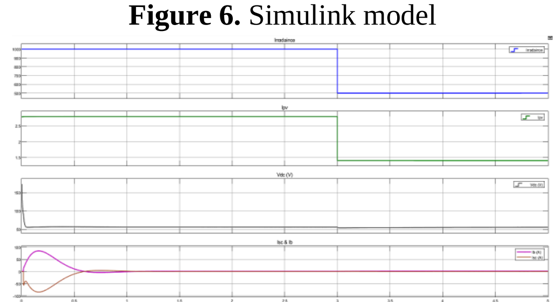

Figure 7. The outputs contain Irradiance, solar Current, Dc-Voltage, Currents of super-capacitor and Battery.

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During load adding the super-capacitor, battery also dis-charging because here having only two sources i.e., battery and super-capacitor. During load dis-connecting here the super-capacitor going for charging mode and battery gets discharged current increases. This condition contains the outputs of when PV and Wind off mode of operation.

Condition:2 When PV-ON Wind-OFF: The graph depicts a steady load, Radiation, PV current,Voltage across load, andCurrent via the battery's super capacitor (With PV, battery, super-capacitor, load). PV current drops as a result of radiation because the super capacitor discharges the battery current during formationfor this condition it contains the outputs if irradiance, solar current, DC voltage, and super-capacitor currents and batteries.

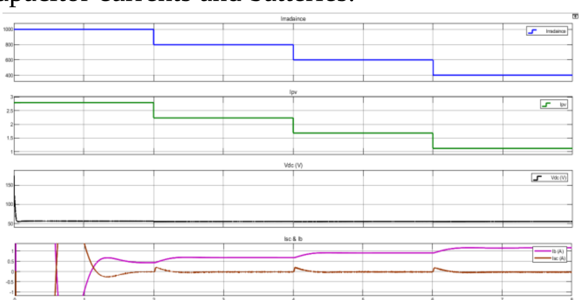

Figure 8. Condition:2 When PV-ON Wind-OFF

Condition3. When PV-OFF Wind-ON: (with wind,battery,supercapacitor,load). The wind (the current reference we are offering is 0, 1,2,3) Vdc will be corrected by PV operation across the load, current wind, super-capacitor, and battery current.The wind filter doesn't provide any power. When the battery's discharging current reaches zero after two seconds and the wind current increases, the total load is completely provided by the wind energy conversion alone.The Super-capacitor charging stops after 4 seconds, and the battery enters charging mode.In these conditions the outputs get only Dc-voltage, Wind currents and Super capacitor and battery currents which is shown below in,

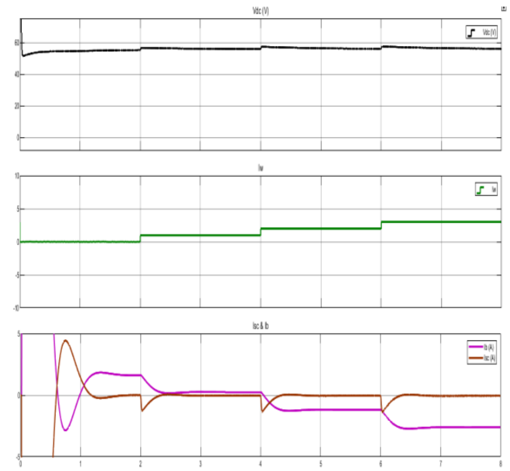

Figure 9. Condition3. When PV-OFF Wind-ON

Condition:4 (When PV-ON Wind-ON): (with PV, wind, battery, supercapacitor,load)PV, wind, Super-capacitor, and Battery current. After three seconds, the PV radiation drops from 1000 to 500, and the super-capacitor and battery start to discharge.After five seconds, the wind current will increase, charging both the supercapacitor and the battery.

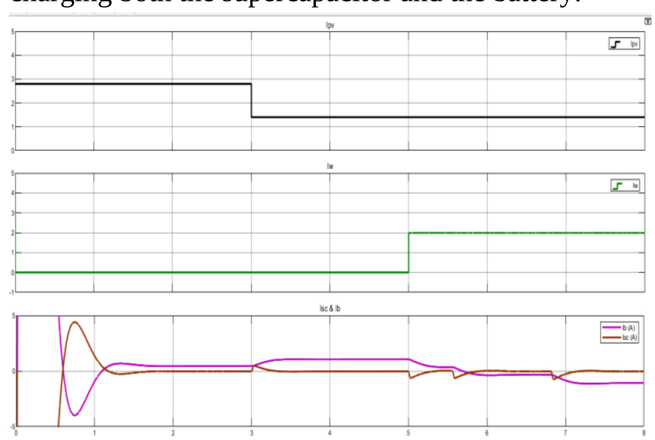

Figure 10. Condition:4 (When PV-ON Wind-ON)

With greater power available, solar and wind energy can now charge the battery and super-capacitor in addition to supplying load**.**For this condition (4) the outputs will be similar but some changes occur when the sources get applied according the main diagram inside the operation of the system.Her the outputs contain solar current (Is), wind current (Iw) and Super-capacitor and Battery currents (Isb) from the overall operation can see in below output.

Extension model with Fuel-cell has been added to previous model, so even used the fuel cell but the outputs which observed is similar to previous report and main paper.So, here can observe the fuel-cell Simulink model below,

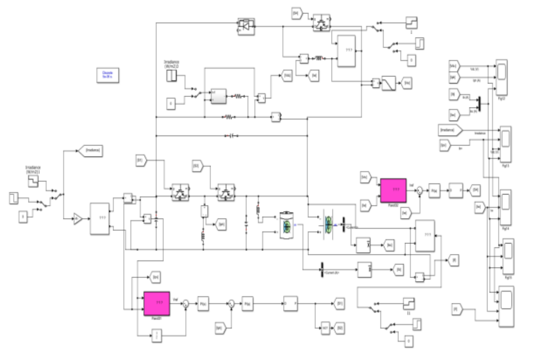

Figure 11. Simulink model with fuel cell.

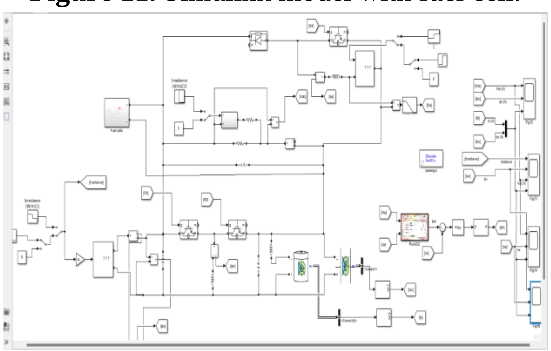

Figure 12. The fuel cell Simulink model

5. CONCLUSION

Through the integration of renewable energy sources, battery storage, and standby generator systems, micro-grids are changing the energy sector. Each micro-grid is different. These sophisticated and adaptable systems can incorporate solar panels, wind turbines, battery banks, diesel gen-sets, and CHP modules, whether they operate singly or in parallel. A micro-grid can provide benefits like power diversification, efficiency, and security to a wide range of applications. Additionally, it can support a business's environmental goals, lower emissions, and maximise expenses. Be sure to comprehend the system's technology and best practises before evaluating a project. A micro-grid built to meet the needs of your company and the surrounding area can yield a healthy return on investment. The efficacy of proposed configuration and control was verified through simulation and experimental results under various cases such as (i) Both PV and wind power is available (ii) Only wind power is available (iii) Only PV power is available and (iv) Both PV and wind is OFF. The satisfactory performance was observed along with basic functionality such as operating renewable sources (PV and wind) at Maximum Power Point and charging and discharging of energy storage based on availability of power. Moreover, it was observed that current stress due to wind, PV and sudden load disturbances on battery was effectively handled by interfacing super-capacitor. Being mentioned that, though dc-link voltage was tightly regulated during all the operating conditions except the case when PV is available, it was observed that variation in dc-link voltage is in permissible range. In comparison with the existing configurations, lesser number of switches, inherent voltage boosting, inherent voltage maintenance of super-capacitor, inherent power-sharing among battery and super-capacitor and reduced sensors are the key highlights of the proposed configuration. The fuel cell can always be relied upon to provide continuous electricity to the microgrid even when solar, batteries, or other resources are not available. This means that while the micro grid configures its many energy resources, including power from the central grid, the fuel cell serves as a sort of backbone on which it can rely.

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