Implementation of PV Systems to Coordinate the Power Exchange between DC - AC Grids Using Control Methods

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Abstract — A Small grid is currently prevailing in the electric power industry. This project provides a modulation technique for the modified coupled induction motor single stage boost inverter based grid system which reduces the leakage current to a great extent. The coordination control schemes among various converters have been proposed to harness the maximum power from renewable sources to minimize power transfer between AC and DC networks. PV system is presented in two cases: Modified CL-SSBI modulated by maximum constant boost MCB control and NSPWM to verify the accuracy of simulation. Because of vitality administration, control, and operation of a half and half lattice are more confounded than those of an individual air conditioning or dc lattice, diverse working methods of a mixture air conditioning/dc matrix have been examined. The Micro grid proposed is used to rescue process of multiple conversions in an individual AC or DC grid to facilitate the connection of various renewable AC and DC sources and loads to power system. The improvement in the power quality is simulated using MATLAB/SIMULINK and quality norms are as per IEC 61400 standards on the grid.

Keywords — Coordination control, MCB control, Micro grid, PV system, renewable.

I. INTRODUCTION

Renewable force transformation frameworks are additional features by using Light emitting diode (LED) lights, electric vehicles (EVs) along with air conditioning force frameworks to retain vitality and lessen CO emanation. May be, dc power from photovoltaic (PV) boards or energy components must be changed over into air conditioning utilizing dc/dc sponsors and dc/air conditioning inverters in request to join with an air conditioner framework. In an air conditioner network, inserted air conditioning/dc furthermore, dc/dc converters are needed for different home and office to supply diverse dc voltages.

To accomplish the objectives to attain towards the solution, power gadgets innovation plays a most vital part to interface distinctive sources and burdens to a shrewd a cross breed air conditioning/dc microgrid is proposed in this paper to decrease procedures of different opposite changes in an individual air conditioning on the other hand dc lattice and to encourage the association of different renewable air conditioning and dc sources and burdens to power framework. Here single unit with administration, control, and operation of a half and half lattice rather those of an individual air conditioning or dc lattice, diverse working methods of a mixture air conditioning/dc matrix have been examined. The coordination control plans among different converters have been proposed to tackle most extreme force from renewable force sources, to minimize force exchange between air conditioning also, dc systems, and to keep up the steady operation of both air conditioning what's more, dc lattices under variable supply and interest conditions when the half and half lattice works in both matrix tied and islanding modes. The propelled force hardware and control advancements utilized in this paper will make a future force network much more quickly.

II. LITERATURE SURVEY

A. PHOTOVOLTAIC TECHNOLOGY

Photovoltaic’s play very important in Research in which the conversion of sunlight to electrical Energy using semiconductors. Here the voltage of substance by exposure to electromagnetic radiation.

The solar cell is the elementary building block of the photovoltaic technology. Solar cells are made of semiconductor materials, such as silicon for conductivity by introducing impurities into their crystal lattice.

Ohmic metal-semiconductor can have n-type and p-type sides of the solar cell, and the electrodes are connected to an external load. When photons of light fall on the cell, they transfer their energy to the charge carriers. The electric field across the junction separates photo-generated positive charge carriers (holes) from their negative ones (electrons).

Fig.1 Photo voltaic Technology

B. BOOST CONVERTER (STEP-UP CONVERTER)

The schematic in Fig. 2(a) shows the basic boost converter is used when a higher output voltage than input is required.
While the transistor is ON, \( V_x = V_{in} \), and OFF, \( V_x = V_o \), assuming the inductor current always remains flowing (continuous conduction). The voltage across the inductor is shown in Fig. 2(b) and the average must be zero for the average current to remain in steady state

\[
\frac{V_{in} t_{on}}{t_{off}} + (V_{in} - V_o) = 0
\]

(2.1)

This can be rearranged as

\[
\frac{V}{V_o} = \frac{t_{on}}{t_{off}} = \frac{1}{1 - D}
\]

(2.2)

And for a lossless circuit the power balance ensures

\[
\frac{I_o}{I_{in}} = (1 - D)
\]

(2.3)

III. MODELING OF CASE STUDY

A. GRID CONFIGURATION:

Fig. 3(a) shows a conceptual hybrid system configuration where various ac and dc sources and loads are connected to the corresponding dc and ac networks. The ac bus of the hybrid grid is tied to the utility grid.

Fig. 3(b) shows a conceptual hybrid system configuration where various ac and dc sources and loads are connected to the corresponding dc and ac networks. The ac bus of the hybrid grid is tied to the utility grid.

A compact hybrid grid as shown in Fig. 3(b) is modeled using the Simulink of MATLAB. 40 kW PV arrays are connected to dc bus for processing dc sources by set-up converter. The frequency disturbance is nullified by capacitor \( C_{pv} \) at the PV output voltage. The duo (wind turbine generator (WTG) & doubly fed induction generator (DFIG)) of 50 kW to process ac sources by ac bus. The energy storage (65 Ah battery) via bidirectional dc/dc converter connected to dc bus. Variable loads of dc and ac are (20 kW–40 kW) & (20 kW–40 kW) respectively. The dc and ac buses have values 400 V and 400 V rms respectively. The R-L-C filter and 3-phase bidirectional dc/ac main converter are connected along with an isolation transformer.

B. GRID OPERATION:

The hybrid grid can operate in two modes.

(i) grid-tied mode and (ii) autonomous mode.

(i) The main converter is to provide stable dc bus voltage and required reactive power through the boost converter and WTG. The converter will be inverter when output power of dc sources is higher that of dc loads and the power direction is from dc to ac, otherwise from the ac to dc. The utility grid gets the power if the total power generation is more than the total load. Otherwise, the hybrid grid will receive power from the utility grid and the battery converter is not necessary here.

(ii) Here the battery must for the power balance and voltage stability. The Energy management system handles the control variations. DC bus voltage is maintained stable by a battery converter or boost converter according to different operating conditions. The voltage of stable and high quality ac bus is obtained by controlling the main converter. Both PV and WTG can work as on-MPPT (maximum power
point tracking) mode or off-MPPT mode based on system operating requirements. Variable wind speed is applied to the WTG and solar irradiation are applied to the PV arrays respectively to simulate variation of power of ac and dc sources and test the MPPT control algorithm.

C. MODELING OF PV PANEL:

Fig. 4(a) Equivalent circuit of a solar cell.

\[
I_{ph} = I_{ph0} + I_{sat}
\]

\[
I_{sat} = \left( \frac{T}{T_r} \right)^{3/2} \exp \left( \frac{1}{k} \left( \frac{1}{T_r} - \frac{1}{T} \right) \right)
\]

Where, \( I_{ph} \) is the current output of the PV panel along load, \( I_{ph0} \) is the short circuit current, \( I_{sat} \) is the saturation current, \( k \) is the Boltzmann constant, \( T \) is the temperature, \( T_r \) is the reference temperature, \( T_m \) is the mechanical torque, \( T_r \) is the rotor speed, \( L \) is the inductance, \( \phi \) is the flux linkage, \( u \) and \( i \) represent voltage and current respectively, \( \omega_1 \) and \( \omega_2 \) are the angular synchronous speed and slip speed respectively, \( \omega_2 = \omega_1 - \omega_r \), \( \omega_r \) is the rotor speed, \( \omega_1 \) is the mechanical torque, \( \omega_2 \) is the rotor speed, \( \omega_3 \) is the angular speed, \( \lambda \) is the pitch angle, \( \beta \) is the tip speed ratio, \( \lambda_s \) is the saturation factor, \( \lambda_m \) is the magnetic flux linkage, and \( \lambda_e \) is the electric flux linkage.

\[
V_s = V_o + R_i \cdot i - K \cdot \frac{Q}{Q + \int i_o \, dt + A \cdot \exp \left( B \int i_o \, dt \right)}
\]

(3.4)

\[
SOC = 100 \left( 1 + \int i_o \, dt \right)
\]

(3.5)

Where, \( R_i \) is the internal resistance of the battery, \( V_o \) is the open circuit voltage of the battery, \( i_o \) is current charge of battery, \( K \) is voltage polarization, \( Q \) is battery capacity, \( A \) is exponential voltage and \( B \) is exponential capacity.

D. MODELING OF BATTERY:

The main parameters of a battery are terminal voltage \( V_t \) and state of charge (SOC) as follows

\[
\begin{align*}
V_t &= V_o + R_i \cdot i - K \cdot \frac{Q}{Q + \int i_o \, dt + A \cdot \exp \left( B \int i_o \, dt \right)} \\
SOC &= 100 \left( 1 + \int i_o \, dt \right)
\end{align*}
\]

Where, \( R_i \) is the internal resistance of the battery, \( V_o \) is the open circuit voltage of the battery, \( i_o \) is current charge of battery, \( K \) is voltage polarization, \( Q \) is battery capacity, \( A \) is exponential voltage and \( B \) is exponential capacity.

E. MODELING OF WIND TURBINE GENERATOR:

Power output \( P_m \) from a WTG is determined by

\[
P_m = 0.5 \rho \omega_2 \lambda_s \beta V_r^2
\]

(3.6)

Where \( \rho \) is air density, \( A \) is rotor swept area, \( \omega_2 \) is wind speed, and \( \lambda_s(\lambda, \beta) \) is the power coefficient, which is the function of tip speed ratio \( \lambda \) and pitch angle \( \beta \).

The mathematical models of a DFIG are essential requirement for its control system. The voltage equations of an induction motor in a rotating \( d-q \) coordinate are as follows:

\[
\begin{align*}
\frac{d u_d}{d t} &= -R_d i_d - \omega_l (i_q - i_d) + \frac{L_m}{L_d} \lambda_s (\lambda, \beta) V_r^2 \\
\frac{d i_d}{d t} &= \frac{1}{L_d} \left( \frac{u_d}{V_r} - R_d i_d - \omega_l (i_q - i_d) \right)
\end{align*}
\]

(3.7)

\[
\begin{align*}
\frac{d u_q}{d t} &= -R_q i_q - \omega_l i_d + \frac{L_m}{L_q} \lambda_s (\lambda, \beta) V_r^2 \\
\frac{d i_q}{d t} &= \frac{1}{L_q} \left( \frac{u_q}{V_r} - R_q i_q + \omega_l i_d \right)
\end{align*}
\]

(3.8)

The dynamic equation of the DFIG

\[
\begin{align*}
\frac{d \lambda_s}{d t} &= L_m \left( \frac{u_d}{V_r} i_d - \frac{u_q}{V_r} i_q - \lambda_0 \omega_2 \lambda_0 \beta \right) \\
\frac{d \lambda_m}{d t} &= \frac{L_m}{L_s} \left( \frac{u_d}{V_r} i_d - \frac{u_q}{V_r} i_q - \lambda_0 \omega_2 \lambda_0 \beta \right)
\end{align*}
\]

(3.9)

\[
\frac{d \lambda_e}{d t} = \frac{L_m}{L_s} \left( \frac{u_d}{V_r} i_d - \frac{u_q}{V_r} i_q - \lambda_0 \omega_2 \lambda_0 \beta \right)
\]

(3.10)

Where the subscripts \( d \) is \( d \)-axis, \( q \) is \( q \)-axis, \( s \) is stator and \( r \) is rotor respectively, \( L \) represents the inductance, is the flux linkage, \( u \) and \( i \) represent voltage and current respectively, \( \omega_2 \) is the angular synchronous speed, \( \omega_2 = \omega_1 - \omega_r \), \( \omega_r \) is the rotor speed, \( \omega_1 \) is the mechanical torque, \( \lambda \) is the pitch angle, \( \beta \) is the tip speed ratio.

Therefore, \( \lambda_s = 0 \) and \( \lambda_m = \lambda_e \). The following equations can be obtained in the stator voltage oriented reference frame as

\[
\begin{align*}
&i_{ds} = -\frac{L_{im}}{L_s} \lambda_s \omega_2 \lambda_0 \beta \\
&i_{ds} = \frac{L_{im}}{L_s} \lambda_s \omega_2 \lambda_0 \beta \\
&\sigma = \frac{L_s L_r - L_m^2}{L_s L_r} \\
&u_{dr} = R_i \lambda_s \sigma \left( i_q - i_d \right) \left( \omega_2 - \omega_1 \lambda_s (\lambda, \beta) \right) \\
&u_{dr} = R_i \lambda_s \sigma \left( i_q - i_d \right) \left( \omega_2 - \omega_1 \lambda_s (\lambda, \beta) \right)
\end{align*}
\]

(3.11)

(3.12)
\[ u_{eq} = R_i i_{eq} + L_i \frac{di_{eq}}{dt} + (\omega_2 - \omega_1)(L_{ni} i_{db} + L_{ri} i_{dq}) \]  

\[ (3.13) \]

IV. COORDINATION CONTROL CONVERTERS:

The different converters in the hybrid grid for obtaining the factors like uninterrupted, high efficiency are as follows.

A. GRID-CONNECTED MODE:

The main intention of converter control is to track the MPPT of the PV array being regulated its terminal voltage. The back-to-back ac/dc/ac converter of the DFIG is controlled to regulate rotor side current to achieve MPPT and to synchronize with ac grid. The energy surplus of the hybrid grid can be sent to the utility system. The role of the battery as the energy storage becomes less important because the power is balanced by the utility grid. In this case, the only function of the battery is to eliminate frequent power transfer between the dc and ac link. The dc/dc converter of the battery can be controlled as the energy buffer using the technique. The main converter is designed to operate bidirectional to incorporate the wind and solar sources characteristics. The control objectives of the main converter are to maintain a stable dc-link voltage for variable dc load and to synchronize with the ac link and utility system.

The combined time average equivalent circuit model of the booster and main converter is shown in Fig. 4(b) based on the basic principles and description for booster and inverter respectively.

The equations of power at the dc and ac links are as follows:

\[ P_{dcL} + P_{acL} = P_{dcL} + P_i \]  

\[ P_{dcL} = P_{dcL} - P_{acL} - P_{ac} \]  

\[ (3.14) \]

\[ (3.15) \]

Where real power \( P_{dcL} \) and \( P_{acL} \) are produced by PV and WTG respectively, \( P_{acL} \) and \( P_{dcL} \) are real power loads connected to ac and dc buses respectively, \( P_{dcL} \) is the power of ac and dc links, \( P_i \) is power injection from the hybrid grid to the utility.

The basic perturbation and observation (P&O) algorithm used to determine the reference value of the solar panel terminal voltage to harness the maximum power. This control scheme for PV system is to track optimal solar panel terminal voltage using the MPPT algorithm with small changes. The zero steady-state error and dynamic response are managed by voltage loop and current loop respectively.

To smoothly exchange power between dc and ac grids and supply a given reactive power to the ac link, PQ control is implemented using a current controlled voltage source for the main converter. Both PI controllers for real and reactive power control and the adjustment of resource conditions and load capacities change as well is set as instantaneous active current \( i_d \) reference. The reactive power compensation command is set as instantaneous reactive current \( i_q \).

The equations at dc bus are as follows:

\[ V_{dc} - V_T = L_1 \frac{di_1}{dt} + R i_1 \]  

\[ (3.16) \]

\[ \begin{align*} 
I_{pe} - i_1 &= C_{pe} \frac{dV_{dc}}{dt} \\
V_T &= V_d (1 - d_1) \\
i_1 (1 - d_1) - C_d \frac{dV_d}{dt} - \frac{1}{R_d} V_d - \delta - i_{ac} &= 0 
\end{align*} \]  

\[ (3.17) \]

\[ (3.18) \]

\[ (3.19) \]

Where \( d_1 \) is the duty ratio of switch ST.

Equations (3.20) and (3.21) show the ac side voltage equations of the main converter in ABC and d-q coordinates respectively.

\[ \begin{align*} 
L_2 \frac{d}{dt} \begin{bmatrix} i_A \\
\omega L_2 \frac{d}{dt} \begin{bmatrix} v_A \\
v_B \\
v_C \end{bmatrix} + \begin{bmatrix} v_{CA} \\
v_{CB} \\
v_{CC} \end{bmatrix} \\
vsd \\
vsq \end{bmatrix} \\
- \frac{R_2}{L_2} \begin{bmatrix} i_A \\
\omega L_2 \frac{d}{dt} \begin{bmatrix} v_A \\
v_B \\
v_C \end{bmatrix} + \begin{bmatrix} v_{CA} \\
v_{CB} \\
v_{CC} \end{bmatrix} \\
vsd \\
vsq \end{bmatrix} + \frac{v_{ad}}{l_d} + \frac{v_{aq}}{l_q} - \begin{bmatrix} v_{ad} \\
v_{aq} \end{bmatrix} \end{bmatrix} \\
= \begin{bmatrix} v_{ad} \\
v_{aq} \end{bmatrix} \end{align*} \]  

\[ (3.20) \]

\[ (3.21) \]

Where \( (v_{CA}, v_{CB}, v_{CC}) \) are ac side voltages of the main converter, \( (v_{SA}, v_{SB}, v_{SC}) \) are voltages across in Fig. 4(b), and \( (id, iq) \), \( (vsd, vsq) \) and \( (vcd, vcq) \) are the corresponding d-q coordinate variables.

The control block diagram is shown below.

Fig. 4 (c) The block diagram for boost and main converter.
The dc-link voltage \( V_d \) got by active power absorbed by capacitor \( C_d \). The PI control provides the negative error \( (V^*_{d} - V_d) \) caused by the increase of \( V_d \) produces a higher active current reference \( i^*_{a} \). Both active current and its reference \( i^*_{a} \) are positive. Therefore, the power surplus of the dc grid can be transferred to the ac side.

The PI control provides the positive voltage error \( (V^*_{d} - V_d) \) caused by \( V_d \) drop makes \( i^*_{a} \) increase as both \( i_d \) and \( i^*_{a} \) are negative. Therefore, power is transferred from the ac grid to the dc side.

The DFIG with control schemes such as the direct torque control (DTC) and direct power control (DPC) is to maintain a stable dc-link voltage of the back-to-back ac/dc/ac converter. The rotor side converter tracks the MPPT of the WTG and manages the stator side reactive power. In Fig. 4.(c) the DTC scheme as the control method for the rotor side converter. The MPPT algorithm is to provide rotor rotational speed using the power and speed characteristic of the wind turbine. The rotational speed \( \Omega_r \) and mechanical power \( P_m \) are used to calculate the electromagnetic torque \( T^*_{em} \).

### MPPT and expected Torque calculation

![Fig.5(d) The DTC control scheme for the rotor side converter.](image)

The –axis rotor side current reference is determined based on \( T^*_{em} \) through stator flux estimation. By controlling current with the feed forward voltage compensation the rotor side d-q voltages are regulated.

#### B. ISOLATED MODE:

In this mode, the boost converter and the back-to-back ac/dc/ac converter of the DFIG operates in on/off-MPPT based on system power balance and energy constraints. The stable voltage and frequency are obtained for the ac grid and operates either in inverter or converter mode for the smooth power exchange between ac and dc links with main converter and the battery converter operates in charging/discharging mode. The balanced equation of powers as follows:

\[
(P_{in} + P_{dc}) = P_{acL} + P_{dcL} + P_{los} + P_b
\]

where \( P_{los} \) is the total grid loss.

Two level coordination controls are used to maintain system stable operation.

At the system level, the energy management system (EMS) based on the system net power \( P_{net} \) and the energy constraints and the charging/discharging rate of battery determines the operation modes of the individual converters. The system control logic diagram is shown in Fig. 5.(a) \( P_{max} \) is defined as the total maximum power generation minus the total load and minus \( P_{los} \). The energy constraints of the battery are determined based on the state of charge (SOC) limits using \( \text{SOC}_{min} \leq \text{SOC} \leq \text{SOC}_{max} \) attained through some estimation methods and the \( P_b \leq \text{P}_{max} \) (constraint of charging and discharging rate).

At local level, the individual converters operate by the EMS. The battery converter operates in the idle, charging, or discharging mode. If \( P_{net} \) is negative the main converter will operate in inverter mode else in the converter mode. If power supply < demand then Load shedding is required and battery will be \( \text{SOC}_{min} \intertext{The equations for the battery converter and dc link are as follows:}
\[
V_d - V_b = i_d \frac{d}{dt} \frac{g_{lb}}{g_{lb} + R_{gb}} \quad \text{(3.23)}
\]
\[
V_d = V_\omega + d_3 \quad \text{(3.24)}
\]
\[
i_{d1} (1 - d_3) - i_{d2} - i_{dc} - i_{b} = C_d \frac{d}{dt} \quad \text{(3.25)}
\]

Where \( d_3 \) and \( 1 - d_3 \) are the duty ratio of the switches \( ST_2 \) and \( ST_3 \) respectively.

The ac side current equations of the main converter in d-q coordinate are as follows:

\[
C_d \frac{d}{dt} \begin{bmatrix} i_{d1} \\ i_{o1} \end{bmatrix} = \begin{bmatrix} i_{d1} \\ i_{o1} \end{bmatrix} \begin{bmatrix} I_d \\ -I_q \end{bmatrix} \begin{bmatrix} 0 \\ 0 \end{bmatrix} - \begin{bmatrix} i_{d1} \\ i_{o1} \end{bmatrix} \quad \text{(3.26)}
\]

Where \( i_{d1} \) and \( i_{o1} \) are d-q currents.
Multi-loop voltage control for a dc/ac inverter is described, where the control objective is to provide a high quality ac voltage with good dynamic response at different load conditions. The coordinated control block diagram for the normal case is shown in Fig. 5(c). To provide a stable dc-link voltage, the dual loop control scheme is applied for the battery converter. The injection current \(I_{in} = i_l(1-d_l) - i_{ac} - i_{dc}\). It should be noted that the output of the outer voltage loop is multiplied by \(-1\) before it is set as the inner loop current reference.

Current \(i_b\) will be positive when flowing into the battery, where the preset dc-link voltage \(V^*_{dc}\) is set to constant 400 V. The decrease in \(V_{dc}\) causes the sudden load increase or decrease of solar irradiation, the positive voltage error \((V^*_{dc} - V_{dc})\) multiplied by PI produces a negative \(i^*_b\) for the inner current loop, which makes the battery to transfer from charging into discharging mode and to rise \(V_{dc}\) back to its preset value \(V^*_{dc}\).

The main converter provides a stable ac bus voltage for the DFIG converter as shown in the bottom of Fig. 5(c).

The coordinated control block diagram for these two converters is described in Fig. 5(d). The boost converter provides a stable dc-link voltage. The main converter is controlled to provide a stable ac bus voltage. The current \(I_b\) in Fig. 5(d) is equal to \(i_{sec} + i_{ac} + i_{dc}d_3\) and \(d_3\) is equal to \((1-d_l)\).

Many anti-islanding detection and control schemes have been developed for reliable operation of distributed generation systems, conventional, power-converter-based distributed generators and various micro grids. The modified are used in the proposed hybrid grid to make the system transfer smoothly from the grid tied to isolated mode.

V. SIMULATION AND RESULTS

A. SIMULATION RESULT FOR PROPOSED HYBRID GRID

![Fig. 6(a) Proposed Hybrid Grid](image)

![Fig. 6(b) The terminal voltage of the solar panel.](image)

![Fig. 6(c) PV output power versus solar irradiation.](image)

![Fig. 6(d) AC side voltage and current of the main converter with variable solar Irradiation level and constant dc load.](image)

**Explanation:**

The system will be feeder reference value between 1sec to 6sec and works in PQ mode in which
the hybrid source output power changes as per load demand. The solar irradiation level will be as shown in Table II

### TABLE II

<table>
<thead>
<tr>
<th>Power</th>
<th>Timing</th>
</tr>
</thead>
<tbody>
<tr>
<td>400W/m²</td>
<td>0.0s to 0.1s</td>
</tr>
<tr>
<td>increases linearly 1000 W/m²</td>
<td>0.1s to 0.2s</td>
</tr>
<tr>
<td>keeps constant 1000 W/m²</td>
<td>0.2s to 0.3s</td>
</tr>
<tr>
<td>decreases 400 W/m²</td>
<td>0.3s to 0.4s</td>
</tr>
<tr>
<td>remains at 400 W/m²</td>
<td>0.4s to 0.5s</td>
</tr>
</tbody>
</table>

Fig. 6(d) shows both the curves of the solar radiation with level times 30 for comparison and the output power of the PV panel. The output power varies from 13.5 kW to 37.5 kW, which approximates to solar irradiation at constant ambient temperature.

### B. HYBRID MODEL

![Hybrid Model](image)

**Fig. 7(a) Hybrid Model**

![DC bus voltage transient response](image)

**Fig. 7(b) DC bus voltage transient response.**

![AC side voltage and current of the main converter](image)

**Fig. 7(c) AC side voltage and current of the main converter with constant solar irradiation level and variable dc load.**

**Explanation:**

Fig. 7(b) shows the voltage (voltage times 0.2 for comparison) and current responses at the ac side of the main converter as shown in Table III.

### TABLE III

<table>
<thead>
<tr>
<th>Power</th>
<th>Timing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000 W/m²</td>
<td>0.3s</td>
</tr>
<tr>
<td>400 W/m²</td>
<td>0.4s at 20</td>
</tr>
</tbody>
</table>

The power is injected from the dc to the ac grid before 0.3 s and reversed after 0.4 s from the current directions.

![Isolation Mode](image)

**Fig. 8(a) Isolation Mode**

![Battery charging current (upper) and SOC (lower) for the normal case.](image)

**Fig. 8(b) Battery charging current (upper) and SOC (lower) for the normal case.**

![Power of Doubly Fed Induction Generator](image)

**Fig. 8(c) Power of Doubly Fed Induction Generator**

![Battery Charging Current](image)

**Fig. 8(d) Battery Charging Current**
Fig. 8(e) AC side voltage versus current

Explanation:
Fig. 8(a) shows the dynamic responses when the ac load increases from 20 kW to 40 kW at 0.3 s with a fixed wind speed 12 m/s. The ac grid injects/ receives power before/ after 0.3 s from/ to the dc grid respectively. The voltage 326.5 V is constant at the ac bus. The nominal voltage 200 V and rated capacity 65 Ah of the battery are selected. Fig. 9.(b) shows the transient process of the DFIG power output, which becomes stable after 0.45s due to the mechanical inertia.

D. HYBRID ISOLATION MODEL

Fig. 9(a) Isolation Mode

Fig. 9(b) DC bus voltage transient response in isolated mode.

E. SIMULATION DIAGRAM FOR ISOLATION MODEL

Fig. 10(a) Isolation Mode

Fig. 10(b) DC bus voltage

Fig. 11 (c) PV output power

Fig. 10(d) battery current

Explanation:
The total power generated is greater than/ less than the total load before/after 0.3s. The Fig. 10(b) shows the battery operation in charging / discharging mode before/ after 0.3s because of the positive/ negative current. The SOC increases and decreases before and after 0.3s respectively. Fig. 10(d) shows that the voltage drops at 0.3s and recovers to 400V quickly. When the system is at off-MPPT mode, the voltage is maintained stable by the boost converter and ac bus voltage is provided by the main converter.

VI. CONCLUSIONS
The “(www.causalproductions.com)” is considered for the Causal Productions which permits the distribution and revision of the templates. To maintain stable system operation different models and coordination control schemes are proposed under various load and resource conditions. The coordinated control strategies are verified by using MATLAB/Simulink simulation where the results show that the hybrid grid can operate smooth and stable in the grid-tied or isolated mode.

The hybrid grids can be used for PV systems on the roofs with LED lighting systems and EV charging systems. Also feasible for some small isolated industrial plants with both PV system and wind turbine generator as the major power supply.
REFERENCES