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Dual Directional DC-DC Converter for Grid Integrated PV, Wind along with Battery System Based on Multi- Source Transformer

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***Abstract:** The green power generation such as solar, wind can also meet the load profile. The goal is to tap the output from different sources using the combination of the PV solar, battery and wind using the power electronics converters system. Excess electricity is injected into grid which charges/discharge the battery when needed. PV solar generation and battery's cycling are employed by dual-directional buck-boost converter. Wind power is used by a transformer connected dual half bridge converter. A monophase phase inverter guarantees the converted output to the grid. This system disturbs with fewer number of converters and with just six power electronics switches by whose size and cost is minimized. The control of twol dc–dc converter for grid connected PV, wind and battery configuration based on multi source transformer connected has been addressed. The primary goal is while not compromising the fundamental requirement this system balances the supply as well as the load requirements, to optimize the distribution of energy from various inputs, to regulate the supply from the green power sources that enhances stability and efficiency of the configuration. The bidirectional dc-dc converter simulation for grid connected hybrid PV, wind and battery systems utilizing multi-sources input transformer and Simulink outputs are showcased on Matlab.*
***Keywords:** PV solar, battery, bidirectional DC power converter, multi-input double half bridge converter, monophase inverter.*

I. INTRODUCTION

Due to increasing of power demand, we need more conventional fuel to generate which is leading the pollution and further effect on eco-friendly. To overcome the causes the consumption of a non- conventional sources has been grown nowadays. The solar and wind are popular sustainable energy sources for their green sustainable nature and in term of cost. The motive is to supply a reliable power and sustain the balance between provision & load by using this source (solar, wind). The combination of PV, wind is nothing but a hybrid system which includes system dependability and performance effectiveness. Sudden change in environment causes the stability of a renewable energy system to overcome the insufficient availability of sources the battery has been taken into an account. The battery in a system helps for storage management, which stores the power generated by renewable sources and supplies the power to grid when required in certain situations. During the daytime PV solar produces the power when the sunlight falls on the PV panels. Meanwhile the humidity helps to generate energy through wind source. During the nighttime battery works on behalf of this sources (solar & wind) which is in needed stored energy in a battery. Not only nighttime it also supplies the power to a grid in a sudden change of an environment conditions. Two way converter helps to assists the battery and provides the battery supply to the load contionuosly. Bidirectional dc power converter which convertes steady state dc to fluctuating dc but this have an disadvantage , this converter needs single phase transformer. The multi source transformer linke bidirecional dc power converter that blend with various power sources. High frequency isolation transformer is employed to safeguard tthe sources (solar, wind and battery) from excessive load . Low voltage side of transformer is utilizes the ac electric energy from wind source. High voltage side full bridge inverter is connected to the load.

Let us explore behavior of a solar and wind coupled power electronics converters, hybrid system integration through a converter having a single dc link [1-15] has been investigated. However, this is subject to disadvantages due to a larger number of power stages causing the system more complex. Emphasis in the system size without compromising its ability the integration is there [7, 8]. The study [7] is particularly aimed at the optimisation of a hybrid system integrated with power stages sizing. The energy flow aspects controlling strategy is in [9-15]. And the battery storage management is studied in Dynamic performance of a stand-alone hybrid PV-wind system with battery storage [9]. The control mode that operates the wind energy coupled with solar energy is comprehended in [14]. In [16]-[19] power converter analyses which has coupled with solar, and wind exists.

Daniel et al. [16] PV wind system has been studied. But utilized for a stand-alone application due to its uncomplicated topology. Low voltage multi-port converter is utilized for a hybrid system to supply a dc load is discussed in [19]. Inter-linked four port topology based on a hybrid system is proposed in [18]. A hybrid PV-wind power generation system with buck/boost connected in multi-input dc-dc converter and full-bridge dc-dc ac inverter is presented by Chen et al. in [20]. A saturate state analysis of grid connected hybrid PV,wind with battery storage is given in [4].

The main objectives of the proposed system are :
1) To provide satisfactory energy supply to grid based on requirement without any interruption.
2) Management of battery charging and discharging through non- convntional sources and grid when needed.
3) Power supply from energy sources should be controlled with effectively by power management system.

II. BLOCK DAIGRAM

The proposed system focuses on system stability, space capability, energy production and budget analysis. In two-way dc-dc converter grid co-ordinated with PV wind and battery has a two-dc links. Two renewable sources (PV, wind) are connected to a common dc supply whereas another dc supply is connected individually to a grid through an inverter. The multi-input transformer is used to combine the power from two sources as an input through a multi-port topology. The multi-source transformers are of 3 types such as:
1) Fully isolated transformer
2) Partially isolated transformer
3) Non isolated transformer

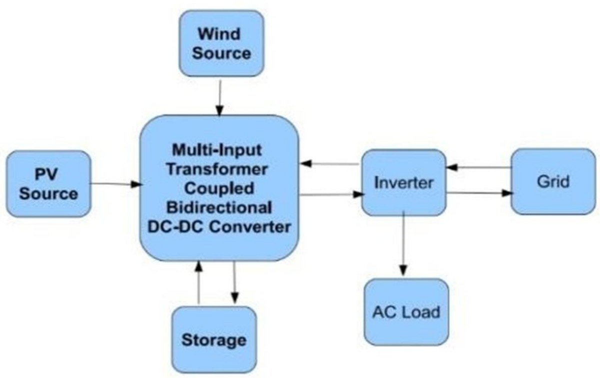

Fig: 1 representation of a block diagram

The multi-input transformer has an advantage of having less no. of components and improved power density. A series- parallel configuration has been employed to derive the multi-port dc-dc converter, and flexibility of energy is limited. A common ground is shared to all output terminals in non-isolated multi-port topology. Buck, boost, buck-boost or bidirectional dc- dc converter are the basic units in non-isolated multi-port transformer. The drawback is that the power cannot delivered to a load simultaneously from multiple inputs, so, the wide range of voltage matching is difficult and makes interruption while controlling the power in this circuit for this reason isolated multiport transformer is used rather than a non-isolated transformer.

To drive a multiport converter magnetic coupling has been approached, were as multi- source transformer is chosen to interconnect each terminal shown in Fig1. The system integrity can manage two renewable sources and a battery. It is trustworthy despite the fact that the two sources PV; wind are working independently or together there will be no difference in the number of components. The system in question (converters) includes transformer with two switch bridge two-way dc-dc converter incorporated with a dual-directional buck boost converter and a monophase full bridge inverter. The modelled topology minimizes the no. of energy transform steps and attain high stability compared to a studied grid connected configurations. since two dc- links are connected with boost dual half bridge converter on either side of large frequency transformer. One side of dc- output is adjusted so that this will control the other side of control strategy easy. The main dc link is co-ordinates with bidirectional step-up\step down converter; secondary side of dc link is connected with full bridge inverter which is inter-connected to a grid. The PV array is in assistance with the battery co-operates with boosting stages.

The boosting features interfere with increased frequency step up transformer. The solar PV was maintained with battery cycling regulating and harvesting power by means of bidirectional buck boost converter. The middle frame of the system designed is a multi-source transformer coupled with bidirectional dc-dc converter. Transformer coupled boost half bridge converter is used for power harvesting from wind source. A unidirectional boost half bridge converter regulates the power flow of a wind source.

III. PROPOSED CONFIGURATION

The suggested configuration system shared with a transformer connects boost dual half bridge bidirectional converter co-ordinate with bidirectional buck boost converter and monophase full bridge inverter. In contrast with current grid connected, the system has lower no. of power conversion stages, high efficiency and only six power electronics switches are utilized.

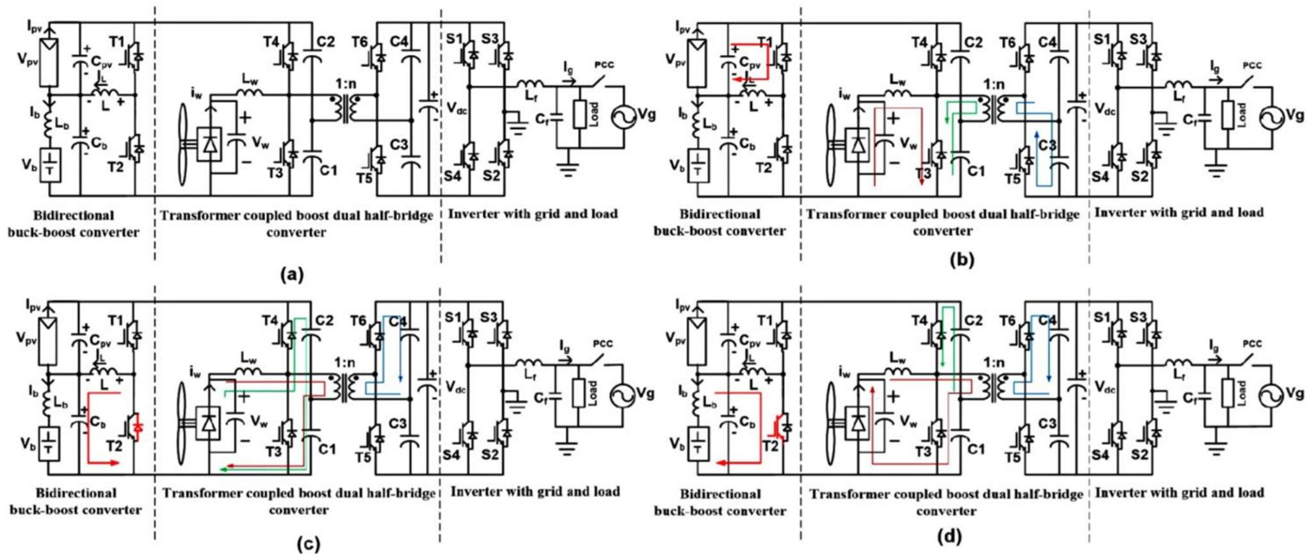

FIG. 2(a) schematic diagram of proposed configuration; FIG. 2(b) operating mode when switch T3 is actived FIG. 2(c): capacitor bank charges when T4 is active; FIG. 2(d): Operating mode when switch T4 active and capacitor C2 is releasing energy

The fundamental topology of suggested system is a multi-source transformer coupled bidirectional dc-dc converter that connects various energy sources and storage elements. A series inductor is connected with the wind source to ensure current, and to achieve smooth variation in source current.

The proposed system is guaranteed with three stages of power conversion like bidirectional buck boost converter, transformer coupled dual half bridge boost converter and inverter with grid. Dual directional buck-boost converter interacts with PV and battery. The power is passed from PV to battery charging (or) feed dc link while also from battery to feed dc link when power falls below. By regulating the duty cycle the voltage (Vpv) step up (or) step down based on input Vb or Vpv. The transformer linked dual half bridge boost include controlling switches like T3, T4, T5, T6 along with capacitor. This system has galvanic isolation by high frequency transformer with turn's ration of 1: n, which is a step-up voltage. Grid and load inverter is controlled using switches S1, S2, S3, and S4. In order to connect grid an inductor and capacitor is utilized as a filter (LC filter). By making switchT3 ON, the source inductor path of current enhances and through low voltage side, switch T3 the capacitor C1 get discharged which is represented in Fig. 4(b). Whereas in high voltage side capacitor C3 powered via anti-parallel diode of switch T5 (forward biased) and secondary transformer. In the condition of switch T4 being turned ON and switch T3 being turned OFF, the current path through an inductor is via the anti-parallel diode of switch T4 and via capacitor bank that has been illustrated in a Fig. 4(c). Nowadays the electrons pass through diodes deteriorated while in transformer primary rises. Turn OFF diode is feasible when the current passing through an inductor is equal to the current passing through the input winding. At the time of switching T4 ON, the capacitor discharges energy through the anti-parallel diode of switch T4, and transformer input. And when switch T4 is switched on the energy is stored in capacitor C4 by anti-parallel diode of T6. Current path is indicated in Fig. 4(d). The voltage at primary side when T3 is switched on $V_p = -nV_{c1}$. The high voltage side is $V_s = nV_p = -nV_{C1} = -V_{C3}$ or $V_{C3} = nV_{C1}$ and primary inductor Lw has voltage across it i.e. Vw. when switch T4 is turn ON at the same time the switch T3 is turned OFF, then the primary voltage is $V_p = V_{C2}$and secondary voltage is $V_s = nV_p = nV_{C2} = V_{C4}$ and inductor has a voltage of$V_w-(V_{C1}+V_{C2})$.

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After simplification

$$V_{C1} + V_{C2} = \frac{V_W}{1 - D_W}$$

Consider capacitor voltage as constant in a steady state at $VC3 = nVC1$, $VC4 = nVC2$. Therefore, the output is given as

$Vdc = VC3 + VC4 = n\frac{V_w}{1-D_w}$ -------- (1)

(1)

The function of the transformer turns ratio and input side duty cycle is the secondary side DC-link output voltage. In the organized setup of FIG 4(a), double directional buck-boost converter charges/discharges the capacitor group C1-C2 of the transformer coupled half-bridge boost converter according to the load requirement. The half bridge boost converter directs energy from the wind source to the capacitor group C1-C2. In charging mode for the battery, when switch T1 is in ON position, the energy gets stored in inductor L. The energy in inductor L is supplied to the battery when T2 is in ON position and T1 is in OFF position. The current in the inductor is negative if the battery release current is greater than the PV current. As the energy stored within an inductor increases when T2 switch is turned ON and reduces when the T1 switch is switched OFF.

It is seen that $Vb = \frac{D}{1-D} Vpv$ —

The dc output of transformer linked boost brige converter is analysed as

$Vdc = (VC1 + VC2) = n(Vb + Vpv) = \frac{nV_w}{1-D_w}$ ------------ (2)

This voltage is n times of input side dc – link voltage. Primary side dc- link voltage is controlled by half bridge boost converter or by bidirectional buck- boost converter. The average value of inductor, PV, and a battery current in a switching cycle is related by $I_L = I_b + I_{pv}$.

IV. ENERGY SOURCE CONTROL SYSTEM

Two way dc–dc converter for load connected PV, wind and battery systems held up with four sources such as PV, wind sources, battery and grid and three energy sinks they are grid, battery, load, which is needed to satisfy the electric flow among these. To manage the power flow the control scheme must be required. Based on the energy manage the control scheme is developed for multi-source system. Therefore, the equation for energy balance of the system is given by

$$VpvIpv + VwIw = VbIb + VgI_g \qquad \text{------------ (3)}$$

For a monophase full bridge inverter, the peak value V_{out} is,

$$\hat{V} = m_a V_{dc} \qquad \text{---------- (4)}$$

And the dc load voltage is,

$$V_{dc} = n(V_{pv} + V_b) \qquad \text{---------- (5)}$$

Hence, by inserting for Vdc in (4), gives

$$Vg = \frac{1}{\sqrt{2}} m_a(Vpv + Vb) \qquad \text{------------ (6)}$$

In the step-up half-bridge converter,

$$Vw = (1 - Dw)(Vpv + Vb) \qquad \text{------------- (7)}$$

Now executing Vw and Vg (3),

$$VpvIpv + (Vpv + Vb)(1 - Dw)Iw = VbIb + \frac{1}{\sqrt{2}} man(Vpv + Vb)I_g \qquad \text{------------- (8)}$$

After the solving,

$$Ib = Ipv\left(\frac{1-D_{pv}}{D_{pv}}\right) + Iw\left(\frac{D_w}{D_w}\right) - Ig\left(\frac{m_a}{D_{pv}}\right) \qquad \text{-------- (9)}$$

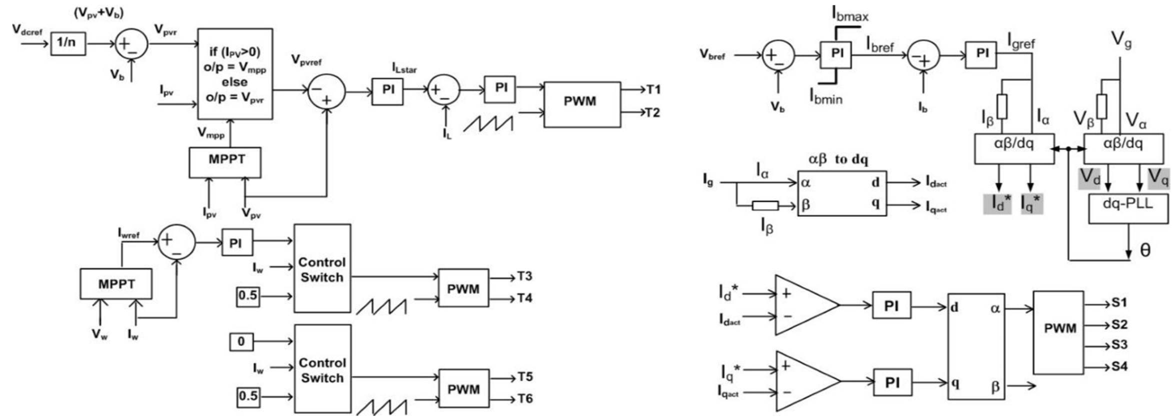


FIG. 5: Control strategy for balancing the energy management

V. SIMULATION AND RESULTS

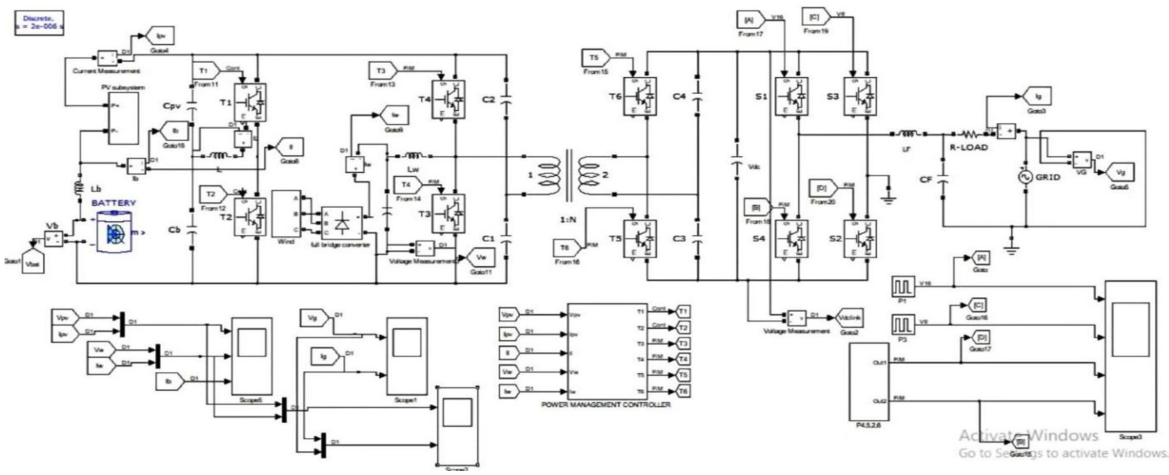


Fig 5.1 designed simulation model

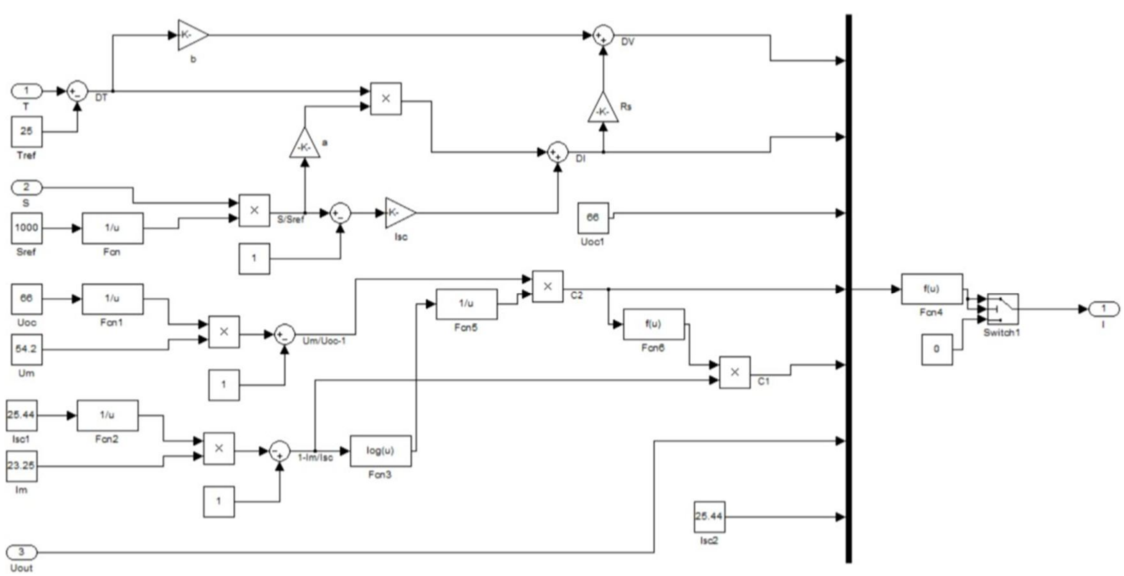


Fig 5.2 simulation model of a solar subsystem -1

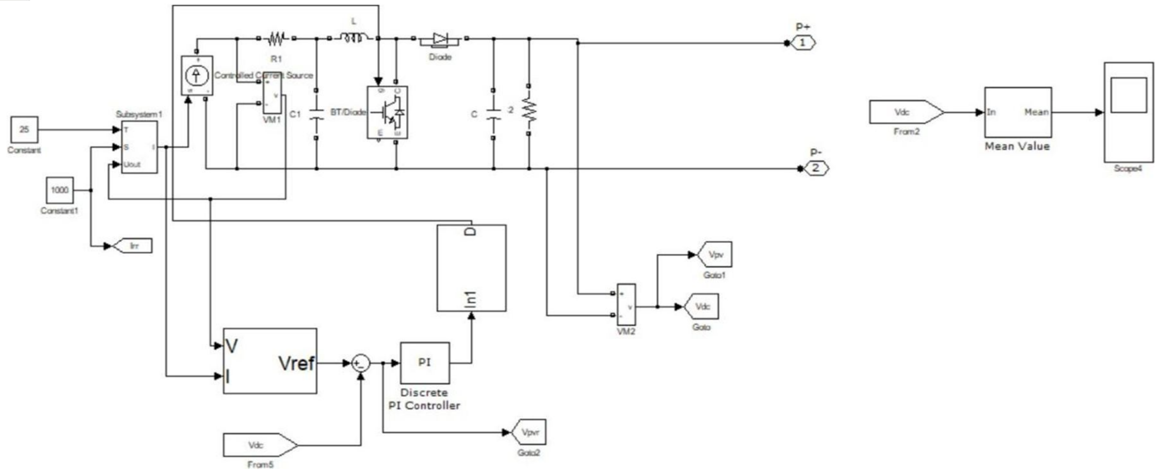


Fig 5.4 simulation model of a solar subsystem -2

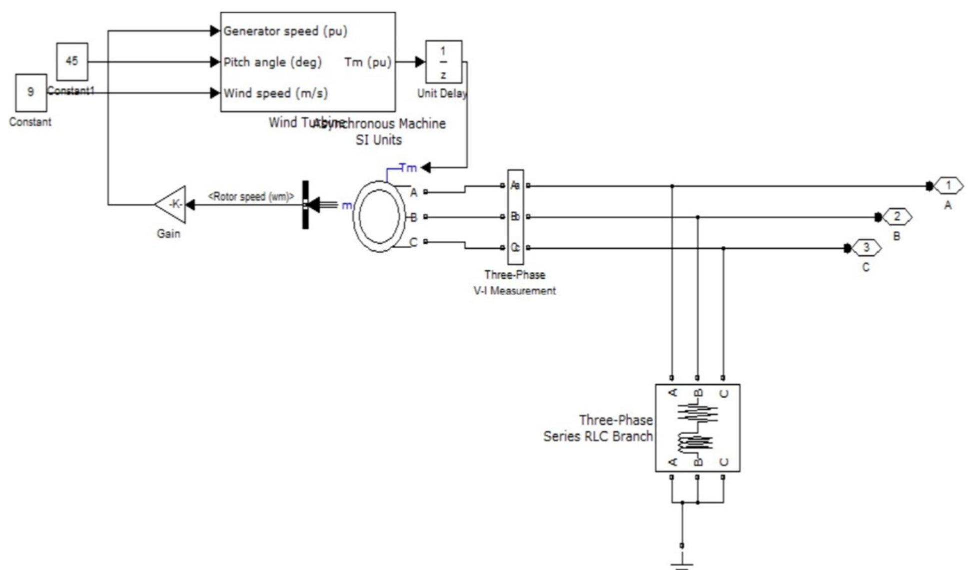


Fig 5.5 simulation model of a wind subsystem

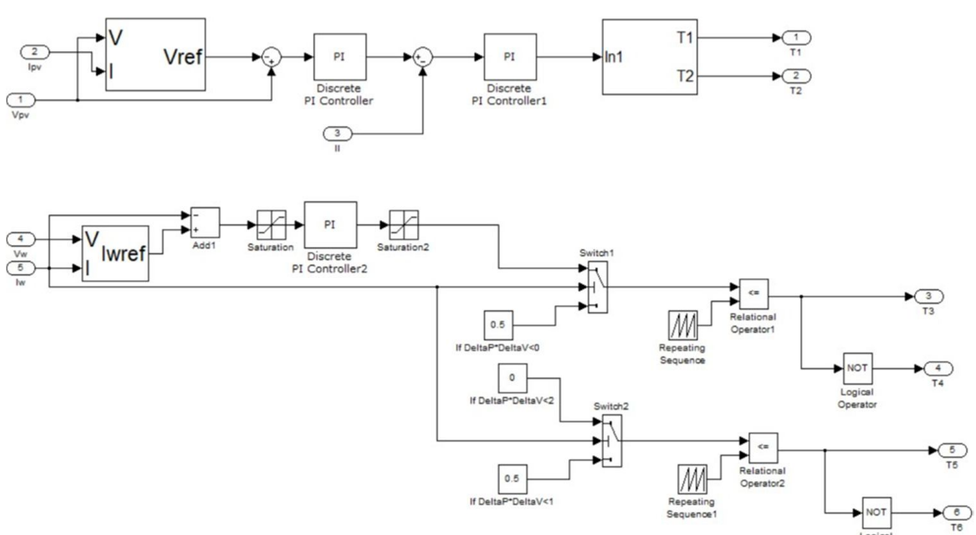


Fig 5.6 simulation model of a power flow management controlling strategy

The proposed detail simulation model is demonstrated on MATLAB/Simulink shown in fig 5.1. The various operation conditions results are also shown. The obtained graphs of voltage and current of sources, solar and wind are shown Fig 6 at an initial condition which is demonstrated on MATLAB.

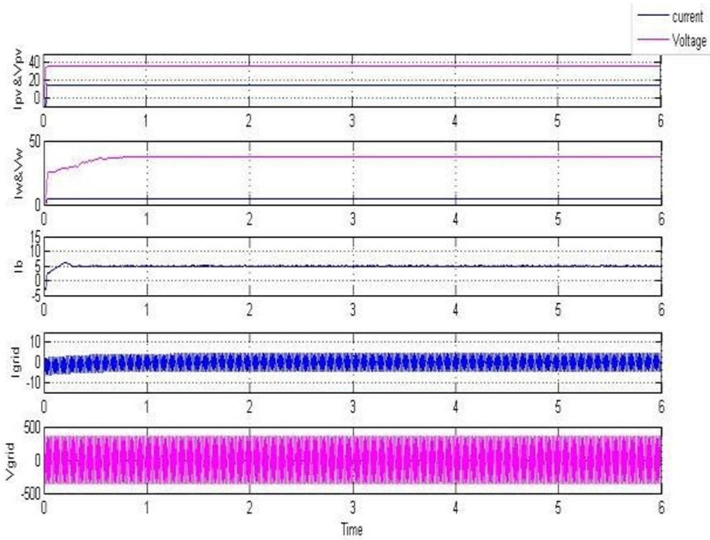


Fig 5.7: Ipv and Vpv, Iw and Vw, Ib, Igrid and Vgrid when both PV and wind sources are available.

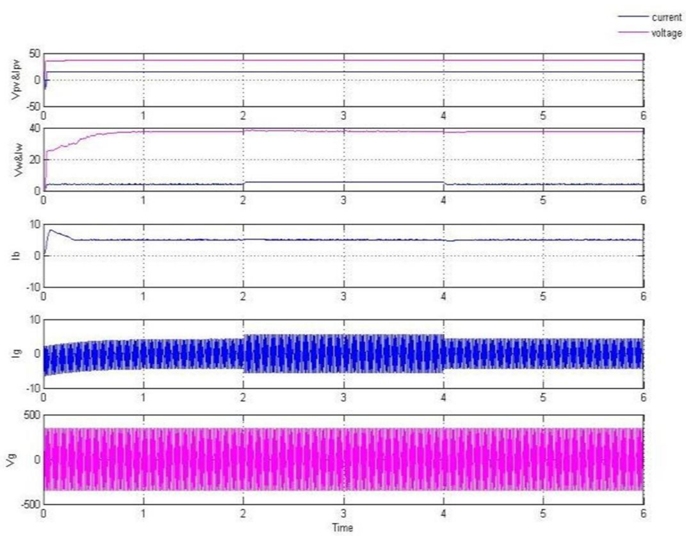


Fig 5.8: Ipv and Vpv, Iw and Vw, Ib, Igrid and Vgrid When PV sources increase.

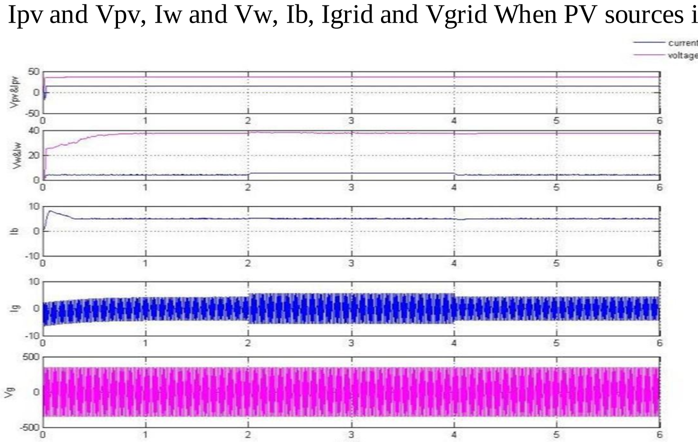


Fig 5.9: Ipv and Vpv, Iw and Vw, Ib, Igrid and Vgrid When wind sources rise.

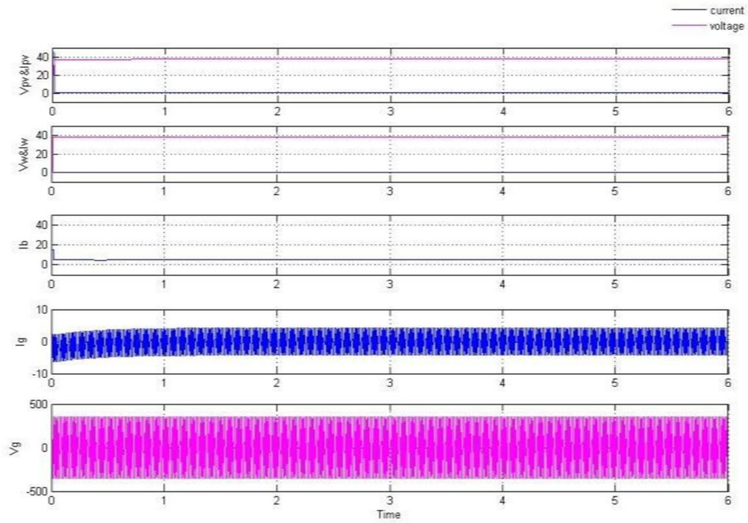
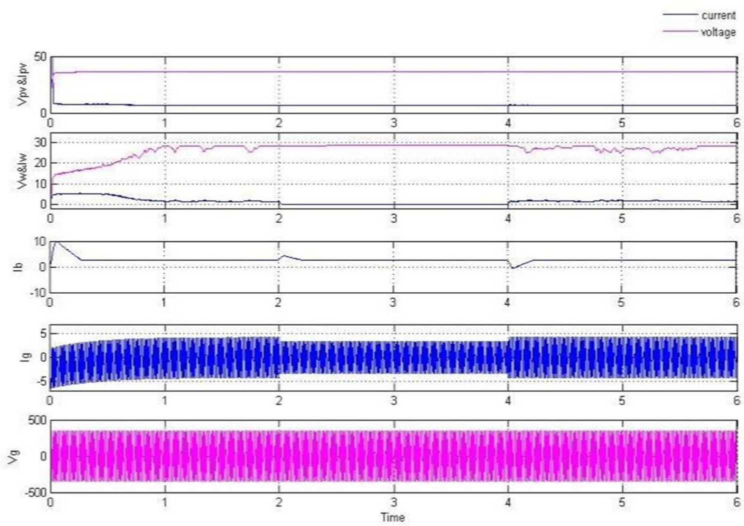
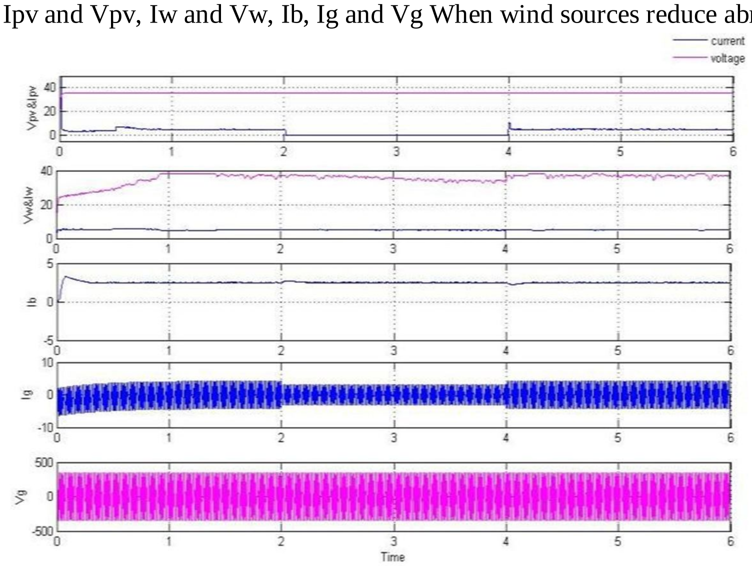


Fig 5.10: Iw and Vw, Ib, Igrid and Vgrid When both the PV and wind sources are not producing.



5.11: Ipv and Vpv, Iw and Vw, Ib, Ig and Vg When wind sources reduce abruptly.



5.12: Ipv and Vpv, Iw and Vw, Ib, Igrid and Vgrid When PV sources reduces abruptly

VI. CONCLUSION

The suggested system "dua`l directional dc-dc converter for grid integrated PV, wind along with battery systems based on multi-source transformer" possesses a sophisticated integration to achieve the greatest amount of power from a renewable power source. The power conversion system assists in converting the necessary conditions. The suggested system possesses an easy modeling, uses fewer conversion systems and switches that makes it more comprehensible. It provides a stable and efficient operation without influencing the service of a battery. Power management technique is also witnessed among different sources. The organized system is illustrated in a MATLAB/Simulink and results are presented in this paper.

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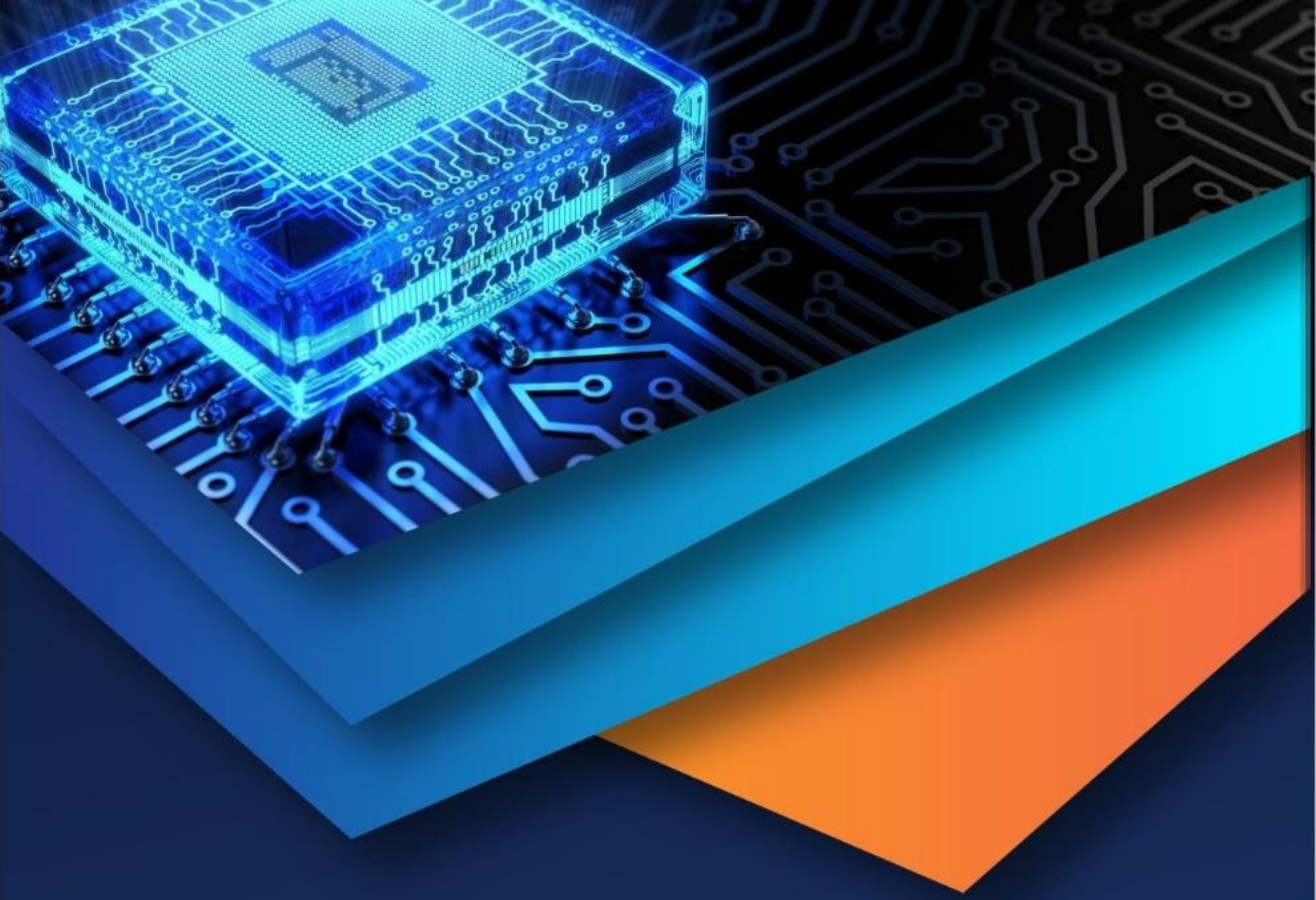

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