Wind Energy Interconnection to Grid at Distribution Level with Fuzzy Logic with Power Quantity Improvement Features

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Abstract:
This paper concentrated on the non conventional energy resources (NCS) are playing vital role with integration of distribution networks by utilizing the advanced power electronic devices. This paper implemented a fuzzy control algorithm for to get more positive feedbacks from the synchronization of grid, when under 3-phase balanced distribution system. The proposed inverter which is worked as a repetitive device for to balancing the distribution system. The inverter with grid maintained two functions. First one, its acts as a power transfer device when the generated power from RES to the grid. Second one, it is acts as a shunt connected APF to mitigate the load harmonics and ripples under the current disturbances by the reactive power compensation. The functions which are reached by the controlling of inverter under normal and abnormal conditions integrated to the loads. The point of common coupling which is used to produce constant power to load side. The implemented simulink model which is simulated in the MATLAB/SIMULINK testes and verified with required reference balanced conditions by Fuzzy controller.

Keywords — *Active power filters (APF), distributed generation (DG), distribution system, grid interconnection, power quality (PQ), and renewable energy.*

I. INTRODUCTION

Electric utilities and end clients of electric force are turning out to be progressively worried about dealing with the creating imperativeness request. 75% of aggregate worldwide vitality interest is issued by the blazing of fossil energizes.

Be that as it may, expanding air contamination, an Earth-wide temperature boost concerns, decreasing fossil powers and their expanding expense have made it important to look towards renewable sources as a future essentialness course of action.

Since the past decade, there has been a colossal enthusiasm for some nations on renewable vitality for force era. The business sector liberalization and government's motivating forces have further quickened the renewable vitality part development.

Renewable vitality source (RES) incorporated at circulation level is termed as dispersed era (DG). The utility is worried because of the high infiltration level of irregular RES in dissemination frameworks as it may represent a risk to organize regarding solidness, voltage regulation and force quality (PQ) issues. In this way, the DG frameworks are required to agree to strict specialized and administrative structures to guarantee sheltered, dependable and proficient operation of general system.

With the headway in force gadgets and systemized control innovation, the DG frameworks can now be effectively controlled to upgrade the framework operation with enhanced PQ at PCC. Notwithstanding, the broad utilization of force gadgets based hardware and non-straight loads at PCC create consonant streams, which may break down the nature of force [1], [2].

For the most part, current controlled voltage source inverters are utilized to interface the irregular RES in disseminated framework. As of late, a couple control techniques for network associated inverters fusing PQ arrangement have been proposed. In [3] an inverter works as dynamic inductor at a sure recurrence to ingest the symphonies current.

Be that as it may, the careful estimation of system inductance progressively is troublesome and may break down the control execution. A comparable methodology in which a shunt dynamic channel goes about as dynamic conductance to soggy out the music in appropriation system is proposed in [4]. In [5], a control technique for renewable interfacing inverter in light of - hypothesis is proposed.

In this procedure both burden and inverter current detecting is required to repay the heap current music. The non-direct load current music may bring about voltage music and can make a genuine PQ issue in the force framework system. Dynamic force channels (APF) are widely used to remunerate the heap current music and burden unbalance at appropriation level.

This outcome in an extra equipment cost. Then again, in this paper creators have fused the elements of APF in the, routine inverter interfacing renewable with the network, with no extra equipment cost. Here, the primary thought is the greatest use of inverter rating which is as a rule over shared in light of discontinuous nature of RES.

It is appeared in this paper the network interfacing inverter can adequately be used to perform taking after imperative capacities: 1) exchange of dynamic force reaped from the renewable assets (wind, sun based, and so forth.); 2) load responsive force interest bolster; 3) current sounds remuneration at PCC; and 4) current unbalance and impartial current pay in the event of 3-stage 4-wire framework. Additionally, with sufficient control of network interfacing inverter, all the four goals can be expert either exclusively or all the while. The PQ limitations at the PCC can along these lines be entirely kept up inside of the utility models without extra equipment cost.

The concept is organized as follows: Area II depicts the framework under thought and the controller for lattice interfacing inverter.

II. SYSTEM DESCRIPTION

The proposed framework comprises of RES joined with the dc-connection of a matrix interfacing inverter as appeared in Fig. 1. The voltage source inverter is a key component of a DG framework as it interfaces the renewable vitality source to the matrix and conveys the created power.

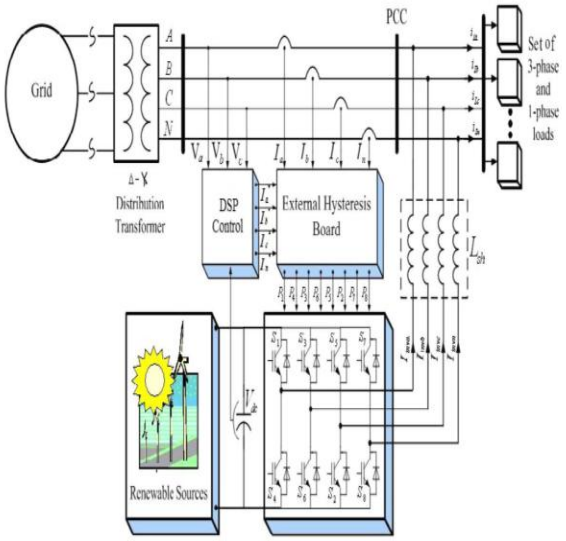


Fig 1: Schematic of Proposed Renewable Based Distributed Generation System.

The RES may be a DC source or an AC source with rectifier coupled to dc-join. More often than not, the energy unit and photovoltaic vitality sources produce power at variable low dc voltage, while the variable velocity wind turbines create power at variable air conditioning voltage. Therefore, the force produced from these renewable sources needs power molding (i.e., dc/dc or air conditioning/dc) before interfacing on dc-join [6]–[8].

The dc-capacitor decouples the RES from framework furthermore permits free control of converters on either side of dc-connection. A. DC-Link Voltage and Power Control Operation Due to the discontinuous way of RES, the created force is of variable nature.

The dc-connection assumes an essential part in exchanging this variable force from renewable vitality source to the network. RES are spoken to as present sources associated with the dc-connection of a lattice interfacing inverter. Fig. 2 demonstrates the orderly representation of force exchange from the renewable vitality assets to the lattice by means of the dc-join.

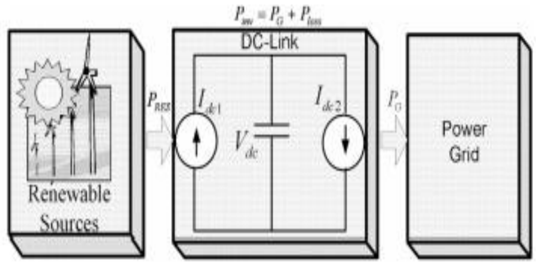


Fig 2: DC – Link Equivalent Diagram

The current infused by renewable into dc-join at voltage level can be given as

$$I_{dc1} = \frac{P_{RES}}{V_{dc}} \qquad (1)$$

Where is the P_{RES} power produced from RES. The present stream on the opposite side of dc-connection can be spoken to as

$$I_{dc2} = \frac{P_{inv}}{V_{dc}} = \frac{P_G + P_{Loss}}{V_{dc}} \qquad (2)$$

Where P_{inv} , P_G and P_{Loss} are total power available at grid-interfacing inverter side, active power supplied to the grid and inverter losses, respectively. If inverter losses are negligible then $P_{RES} = P_G$

Control of Grid Interfacing Inverter:

The control chart of network interfacing inverter for a 3-stage 4-wire framework is appeared in Fig. 3. The fourth leg of inverter is utilized to remunerate the nonpartisan current of burden. The primary point of proposed methodology is to manage the force at PCC amid:

1) $P_{RES} = 0$;

2) $P_{RES} < total\ load\ power(P_L)$; and

3) $P_{RES} > P_L$.

While performing the force administration operation, the inverter is effectively controlled in a manner that it generally draws/supplies essential dynamic force from/to the framework.

On the off chance that the heap joined with the PCC is non-straight or unequal or the mix of both, the given control approach likewise repays the sounds, unbalance, and unbiased current. The obligation proportion of inverter switches are shifted in a force cycle such that the blend of burden and inverter infused force shows up as adjusted resistive burden to the matrix.

The regulation of dc-connection voltage conveys the data in regards to the trading of dynamic force in the middle of renewable source and lattice. Hence the yield of dc-connection voltage controller results in a dynamic current (I_m).

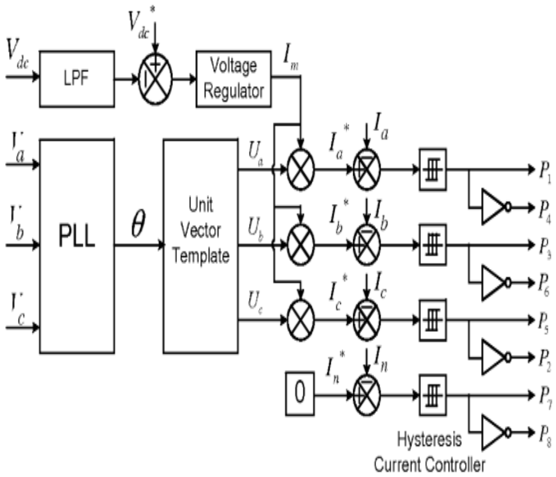


Fig 3: Block Diagram Representation of Grid Interfacing Inverter Control.

The increase of dynamic current segment (I_m) with solidarity lattice voltage vector layouts $(U_a, U_b \text{ and } U_c)$, a produces the reference grid currents $(I_a^*, I_b^* \text{ and } I_c^*)$.

The reference matrix unbiased current I_n^* is set to zero, being the momentary whole of adjusted lattice streams.

The network synchronizing point (θ) acquired from stage bolted circle (PLL) is utilized to create solidarity vector layout as [9]–[11]

$$U_a = Sin(\theta) \quad (3)$$

$$U_b = Sin(\theta - \frac{2\pi}{3}) \quad (4)$$

$$U_c = Sin(\theta + \frac{2\pi}{3}) \quad (5)$$

The real dc-join voltage (V_{dc}) is detected and went through a first-request low pass filter (LPF) to wipe out the vicinity of exchanging swells on the dc-join voltage and in the produced reference current signs.

The distinction of this filtered dc-link voltage and reference dc-join voltage (V_{dc}^*) is given to a discrete-PI controller to keep up a consistent dc-join voltage under changing era and burden conditions. The dc-join voltage blunder $V_{dcerr(n)}$ at nth testing moment is given as:

$$V_{dcerr(n)} = V_{dc(n)}^* - V_{dc(n)}^* \quad (6)$$

The output of discrete-PI regulator at nth sampling instant is expressed. Where $K_{PV_{dc}} = 10$ and $K_{IV_{dc}} = 0.05$ are proportional and integral gains of dc-voltage regulator. The instantaneous values of reference three phase grid currents are computed as

$$I_a^* = I_m . U_a \quad (8)$$

$$I_b^* = I_m . U_b \quad (9)$$

$$I_c^* = I_m . U_c \quad (10)$$

The unbiased present, present if any, because of the heaps associated with the nonpartisan conductor ought to be repaid by forward leg of framework interfacing inverter and therefore ought not be drawn from the matrix. As it were, the reference current for the matrix impartial current is considered as zero and can be communicated as

$$I_c^* = 0 \quad (11)$$

The reference grid currents $(I_a^*, I_b^*, I_c^* \text{ and } I_n^*)$ are compared with actual grid currents $(I_a, I_b, I_c \text{ and } I_n)$ to compute the current errors as

$$I_{aerr} = I_a^* - I_a \quad (12)$$

$$I_{berr} = I_b^* - I_b \quad (13)$$

$$I_{cerr} = I_c^* - I_c \quad (14)$$

$$I_{nerr} = I_n^* - I_n \quad (15)$$

These present mistakes are given to hysteresis current controller. The hysteresis controller then produces the exchanging heartbeats $(P_1 \text{ to } P_8)$ for the door drives of network interfacing inverter. The normal model of 4-leg inverter can be acquired by the accompanying state space mathematical statements

$$\frac{dI_{Inva}}{dt} = \frac{V_{Inva} - V_a}{L_{sh}} \quad (16)$$

$$\frac{dI_{Invb}}{dt} = \frac{V_{Invb} - V_b}{L_{sh}} \quad (17)$$

$$\frac{dI_{Invc}}{dt} = \frac{V_{Invc} - V_c}{L_{sh}} \quad (18)$$

$$\frac{dI_{Invn}}{dt} = \frac{V_{Invn} - V_n}{L_{sh}} \quad (19)$$

$$\frac{dV_{dc}}{dt} = \frac{I_{Invad} + I_{Invbd} + I_{Invcd} + I_{Invnd}}{C_{sh}} \quad (20)$$

Where V_{Inva} , V_{Invb}, V_{Invc} and V_{Invn} are the three-phase ac switching voltages generated on the output terminal of inverter. These inverter yield voltages can be demonstrated as far as quick dc transport voltage and exchanging beats of the inverter as

$$V_{Inva} = \frac{(P_1 - P_4)}{2} V_{dc} \quad (21)$$

$$V_{Inva} = \frac{(P_3 - P_6)}{2} V_{dc} \quad (22)$$

$$V_{Inva} = \frac{(P_5 - P_2)}{2} V_{dc} \quad (23)$$

$$V_{Inva} = \frac{(P_7 - P_8)}{2} V_{dc} \quad (21)$$

Same way the charging currents I_{Invad} , I_{Invbd}, I_{Invcd} and I_{Invnd} on dc bus due to the each leg of inverter can be written as

$$I_{Invad} = I_{Inva} (P_1 - P_4) \quad (25)$$

$$I_{Invbd} = I_{Invb} (P_3 - P_6) \quad (26)$$

$$I_{Invcd} = I_{Invc} (P_5 - P_2) \quad (27)$$

$$I_{Invad} = I_{Inva} (P_7 - P_8) \quad (28)$$

The exchanging example of each IGBT inside inverter can be figured on the premise of mistake in the middle of genuine and reference current of inverter, which can be clarified as:

If $I_{Inva} < (I^*_{Inva} - h_b)$, then upper switch S_1will be OFF $(P_1 = 0)$ and lower switch S_4will be ON $(P_4 = 1)$ in the phase “a” leg of inverter.

If If $I_{Inva} > (I^*_{Inva} - h_b)$, then upper switch S_1will be ON $(P_1 = 0)$ and lower switchS_4 will be OFF $(P_4 = 0)$ in the phase “a” leg of inverter.

Where h_b is the width of hysteresis band. On On the same guideline, the exchanging heartbeats for the other staying three legs can be inferred.

III. PROPOSED SIMULINK MODEL

The proposed grid connected simulink model is shown in below figure 4. The supply voltage which has to transfer the voltages to receiving side by utilizing distribution transformers. Generally the receiving side voltages not maintained constant required power due to different issues such as impedance losses, voltage sags and swells etc, so always the power system operated under inaccurate power quality conditions.

In order to enhance the power quality conditions here grid connected system is provided with three-leg wind generation. The generated wind voltage has to be transmitting to load side without any disturbances even the loads having linear conditions as well as non linear variations.

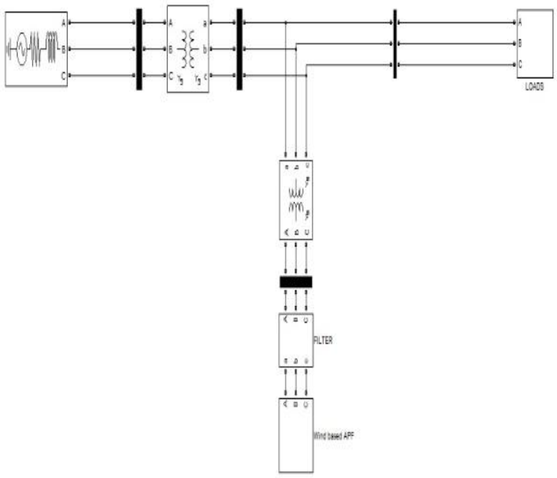


Fig 4: Proposed Wind Based Grid Connected Model

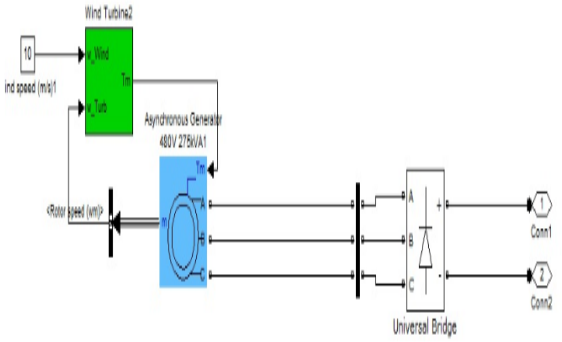


Fig 5: Wind Model for the Proposed System

The RES may be a DC source or an AC source with rectifier coupled to dc-joint. In this paper wind turbine is utilized as a RES, the variable rate wind turbines create power at variable air conditioning voltage. In this way, the power produced from these renewable sources needs to change over in dc before associating on dc-join. The simulink model of wind model is given in Fig 5. Wind turbine creates a variable air conditioning supply; this variable air connecting so as to condition supply is changed over into dc a rectifier at yield side.

Under non-sinusoidal and/or unbalanced system voltages, it is difficult to execute a shunt dynamic filter that fulfils at the same time steady genuine force depleted from the system, sinusoidal repaid current and proportionality between the supply side voltage and the required remunerated current.

This technique will defeat the two of the three concerns said above. The Clarke Transformation is no more utilized and the force meanings of the p-q hypothesis are not straightforwardly utilized. This technique utilizes the abc-line streams, which keeps away from the Clarke Transformation. The deliberate streams from the nonlinear burden, together with a hearty synchronizing circuit (PLL control circuit) shape a compact controller for shunt dynamic channel. The proposed controller powers the shunt dynamic channel to repay the heap current such that the current depleted from the system gets to be sinusoidal and adjusted (contain just the basic positive-arrangement segment), even under bended and/or uneven system voltage.

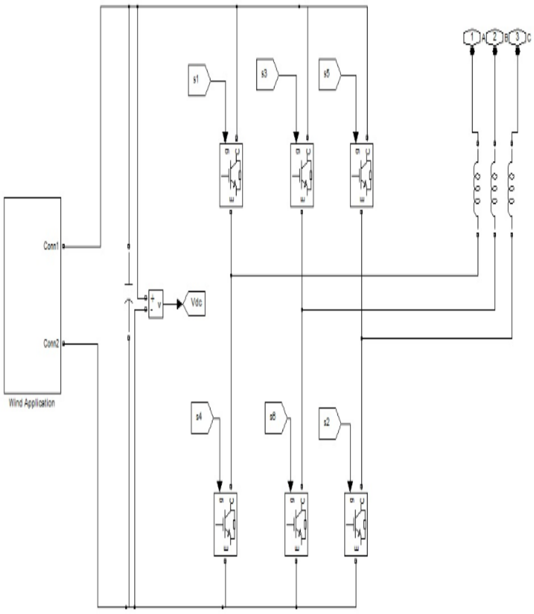


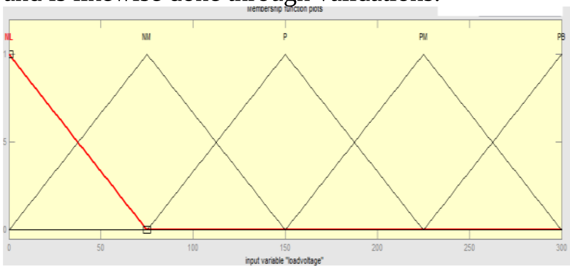
Fig 6: Three Phase Three Leg Voltage Source Converter Models

A. Fuzzy Logic Controller:

The disservice of PI controller is its powerlessness to respond to sudden changes in the mistake signal, ε, on the grounds that it is just equipped for deciding the momentary estimation of the band width signal without considering the change of the ascent and fall of the band, which in numerical terms is the subsidiary of the band controller signified as Δε.

To take care of this issue, Fuzzy logic control as it is appeared in Fig 7 is proposed. T he determination of the yield control sign, is done in a deduction motor with a standard base having if-then guidelines as "IF ε is .... What's more, Δε is......., AND THEN yield is........"

With the standard base, the estimation of the yield is changed by estimation of the blunder hysteresis controller rupture and determination of the tenet base is done utilizing experimentation systems and is likewise done through validations.



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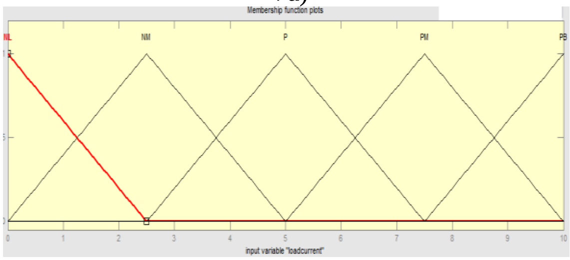

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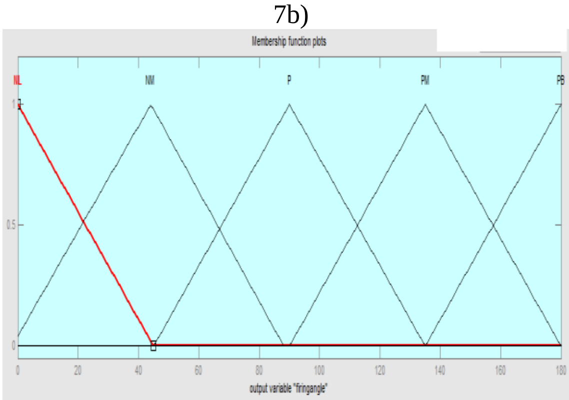


7c)

Fig 7: Fuzzy Logic Controller Membership Functions. A) Input Functions E B) Error Input Function ΔE C) Output Functions

E/ΔE	NL	NM	P	PM	PB
NL	PB	PB	NM	NM	NL
NM	PB	PB	NM	P	NL
P	P	PM	NM	NM	P
PM	NM	P	NM	NM	PM
PB	NL	NM	NM	NL	NL

Fig 8: Fuzzy Rules for the Proposed System

B. Controlling Strategy:

The hysteresis control has been utilized to keep the controlled current inside a characterized band around the references. The status of the switches is resolved by band width controller. At the point when the current is expanding and the mistake surpasses a sure positive esteem, the status of the switches changes and the present starts to diminish until the blunder achieves a sure negative worth. At that point, the switches status changes once more. Contrasted and direct controllers, the non-straight ones taking into account hysteresis techniques permit quicker element reaction and better strength as for the variety of the nonlinear burden. A disadvantage of the hysteresis techniques is the exchanging recurrence which is not steady and can produce a huge side music band around the exchanging recurrence.

Fig. 9 demonstrates the control calculation of proposed converter with fuzzy logic controller. Fuzzy logic controller directs the DC join voltage. The in-stage segments of inverter reference streams are in charge of force element rectification of burden and the quadarature segments of supply reference ebbs and flows are to control the AC system voltage at grid.

The yield of fluffy rationale controller over the DC transport voltage is considered as the sufficiency of the in-stage part of supply reference streams and the yield of fuzzy logic controller.

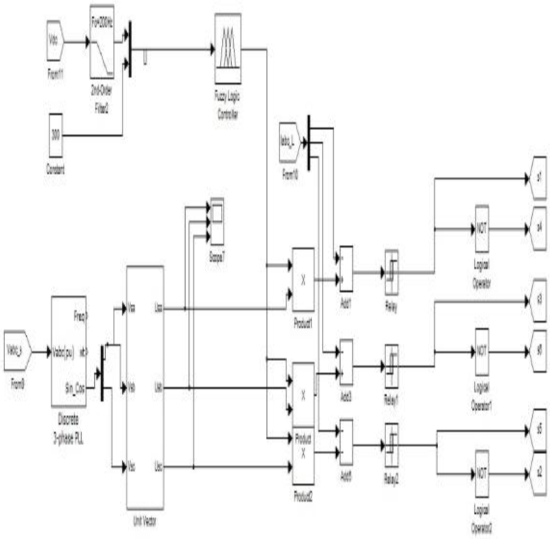
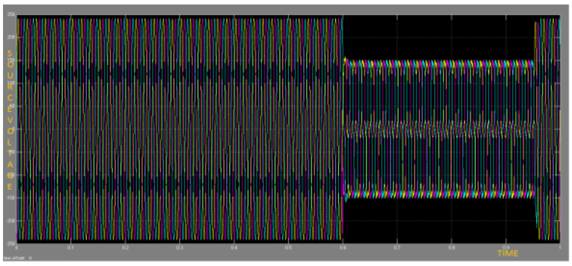


Fig 9: Hysteresis Controller For The Proposed Model

Over AC terminal voltage is considered as the plentifulness of the quadarature segment of supply reference currents. The immediate instantaneous reference streams are obtained by including the in-stage supply reference currents from the unit vector signal and quadarature supply reference currents when the reference supply streams are created, a transporter Over AC terminal voltage is considered as the plentifulness of the quadarature segment of supply reference currents.

Less hysteresis PWM controller is utilized over the detected supply currents and immediate reference currents to produce gating switching pulses to the IGBTs of converter.

The controller controls the converter streams to keep up supply ebbs and flows in a band around the wanted reference current qualities. The hysteresis controller creates fitting exchanging heartbeats for six IGBTs of the VSI working as converter.



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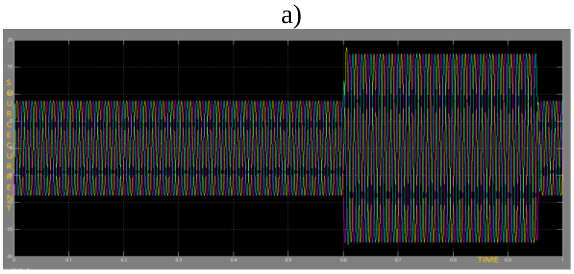

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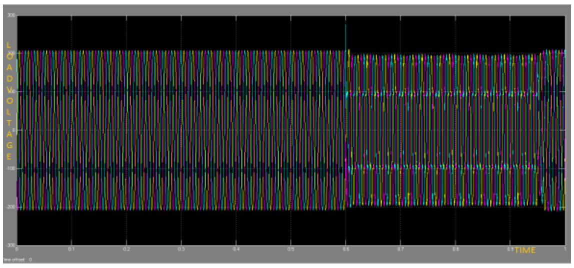
Fig 10: A) Source Side Voltage B) Source Current



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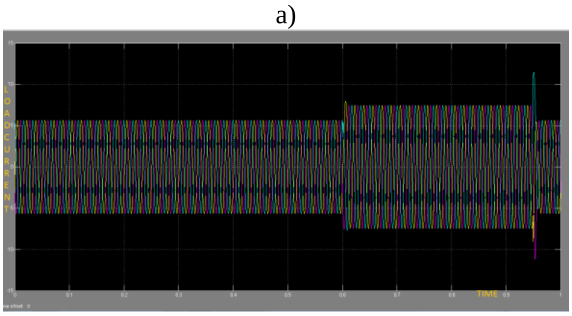
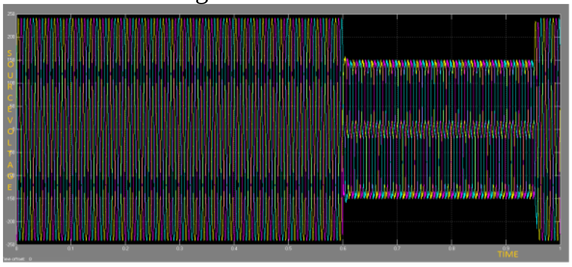


b)

Fig 11: Load Side Voltage B) Load Current

The voltage source converter having six IGBT's these are performed to convert dc voltages into ac voltages. These operated with the help of hysteresis controller with fuzzy controller. The generated firing pulses connected to VSI it can convert the required voltage levels even under faulted conditions also.

The faulted conditions detected very effectively to compensate the problems by providing VSI with filters. Finally the issues are compensated and the voltage and current levels are maintained effectively at grid side. The simulated results are shown in below figures.



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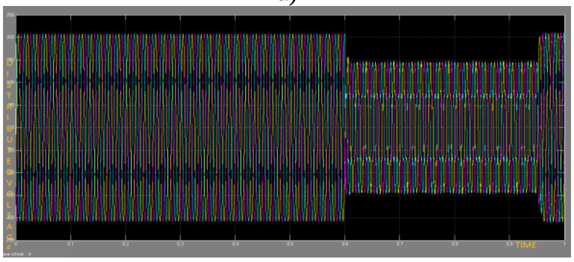

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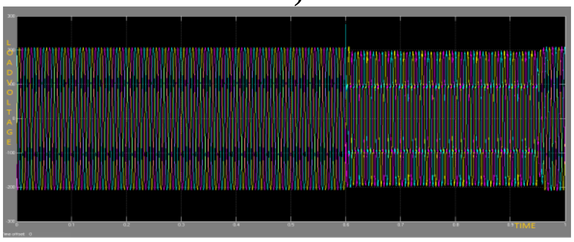
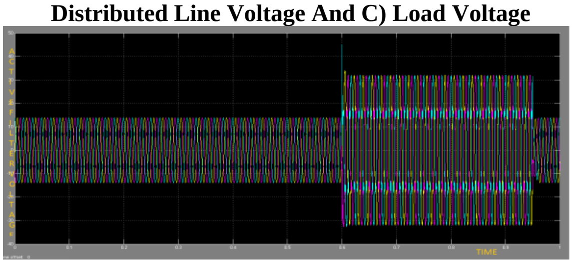


Fig 12: A) Results Of Source Side Voltage, B) Distributed Line Voltage And C) Load Voltage



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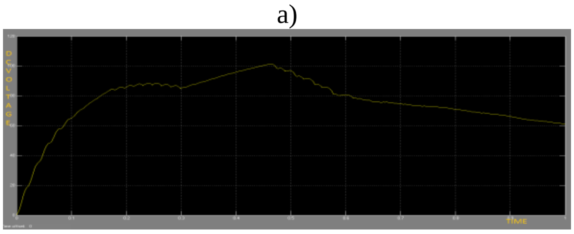


b)

Fig 13: A) Generated Voltage From The Active Power Filter And B) Dc-Link Voltage

Parameters	Ratting
Grid Voltage	100V
Grid Current	15A
Load Current	15A
Inverter Current	40A

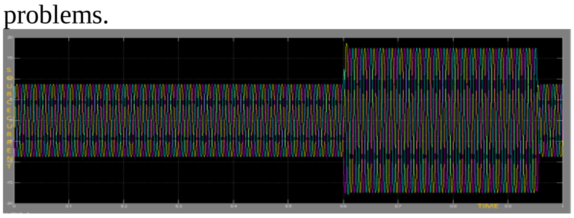
Table 1: Existed Model Simulation Results

Parameters	Ratting
Source Voltage	240V
Source Current	8A
Distributed Voltage	200V
Distributed Current	8A
Load Voltage	200V
Load Current	8A
Active Power Voltage	30V
Dc Voltage	100V

Table 2: Proposed Model Wind Model Results

The output results are shown in figures. Fig 10 gives the information related to the source side voltage and currents. Fig 11 gives the load side voltage and current from the grid connected model. Fig 12 gives the source side voltage with problem, distribution line voltage levels and the load side voltage after compensation of problems.

Fig 13 explains the active power filter generated voltage levels at faulted conditions and also provided the dc-link voltage levels from rectified voltages from the wind turbine. Fig 14 represents the generated source side currents and distribution line current and load currents after compensation of problems.



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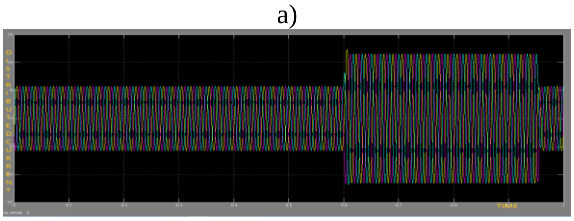

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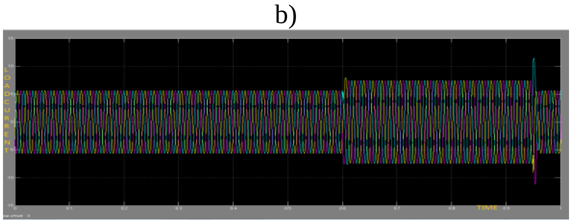

c)

Fig 14: A) Results Of Source Side Current, B) Distributed Line Current And C) Load Current

IV. CONCLUSION

Here in this paper introduced a new control of an existing grid interconnected inverter to improve the power quality at PCC for a 3-phase Distribution system. It has been shown that the grid interconnected inverter can be accurately used for power conditioning without affecting its general operation of real power transfer. The grid interconnected inverter with the proposed approach used to

1) Inject real power produced from RES to the grid , and/or
2) Operate as a shunt active filter (APF)

This control technique thus eliminates the necessity for add extra power conditioning equipment to improve the power quality at the PCC. General LMLAB/Simulink simulation as well as the DSP based experimental results have authenticated the proposed system and have shown that the grid interconnected inverter can be used as multipurpose equipment.

It is additional demonstrated that the power quality enhancement can be accomplished under three different operating scenarios 1) $P_{RES} = 0$, 2) $P_{RES} < P_{load}$ 3) $P_{RES} > P_{load}$. The presence of faulted conditions in source side which are compensated with the hysteresis band controller with fuzzy logic controller.

The hysteresis band controller activated with error less signals currents provided from the PLL, unit vectors and fuzzy logic controllers. The firing pulses generated from the band controller are fed back to VSI and it can maintain the constant required power levels from the distribution system.

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