MMC Based Micro Grid with Integrated Wind Energy System

Dr. KONA NARESH VARMA NIT,BBSR, konanaresh@thenalanda.com

Mr.SUBHENDU MOHAN KUMAR BASANTIA NIT,BBSR subhendumohan@thenalanda.com

Abstract— This article proposesa new method ofintegrated wind energy based micro grid (µG) to achieve harmonic mitigation across its output with constant voltage; nevertheless, particular attention has been provided to the form and function of modular multilevel converter (MMC) with multi-winding transformer connected to grid. MMC is implemented with an advanced voltage controller, tuned to control the voltage at its output. The system is examined for constant and variable wind speeds and their result has been analyzed. The proposed scheme shows its effectiveness by theoretical calculations, verified by simulation and experimental results.

Keywords: **integrated wind energy based micro grid (µG), modular multilevel converter (MMC) and multi-winding transformer connected to grid.**

Introduction—

An electrical distribution technology advances into the 21st Century, where many new technologies are becoming evident to change the necessities of energy delivery. These changes are being motivated from both the demand side; where higher energy availability and efficiency are desired and from the supply side; where the integration of distributed generation (DG) and peak-saving technologies must be accommodated. Distribution systems consisting of distributed generation and controllable loads with the ability to operate in both grid-connected and island modes are an important class of the so-called µGpower system. Micro Grids are designed to separate or island from the main grid and operates alone and serve their consumers' power needs when grid problems occur and reconnects to the grid once the problems are solved [6].

A micro grid is a small power system consisting of one or more distributed generation units that can be operated independently from the large power system. In the coming years the dispersion of DG systems will cause a change of pattern from main generation of power systems. It is predictable that the main utility grid will be a combination of interconnected micro grids. However the consumption of energy can be a problem if it was not able to manage the energy by novel kinds of uninterrupted power supplies. The new innovations in distributed power generation system combined with technological developments in power electronics leds to new idea of future network technologies such as micro grids[7]. Many types of distributed generation such as photovoltaic, wind turbines and fuel cells are interfaced to the network through power electronic converters. These sources are more flexible in their operation and control compared to the conventional power systems. The micro grid can meet their extraordinary needs such as reducing feeder losses, supporting local voltages, increased local reliability, Reduced greenhouse gases and pollutant emission, Minimized overall energy consumption, increased efficiency through the use of voltage sag correction, waste heat or providing uninterrupted power supply[8].The proposed micro-grid technologies mainly include operation control such as the control problems between various micro-sources, switching process in micro-grid connection/isolation operating state in islanding[9-10]. The basic schematic of µG is shown in fig.1.

In this article interconnection of DER's has been done with Modular Multilevel Converter and its brief introduction has been given in section.A.

A. Modular Multi-Level Converter:

The novel power converter topology for Modular Multi level Converter (MMC) has been intensively researched and developed, for attractive features like high modularity, simple scalability, low expense of filters, robust control, simple in design and redundancy. This converter is composed by several identical power cells connected in series, each one build up with standard components, enabling the connection to high voltage poles. Although the MMC and derived topologies offer several advantages, they also introduce a more complex design of the power circuit and control goals, which have been the main reasons for the recent and ongoing research. Furthermore, Medium Voltage Converters are an interesting area for the application of MMCs such as STATCOMs and drives etc.,[1].

Due to several advantages of MMC compared with conventional inverters [1], work was performed on the different topologies, harmonic control, dynamics of MMCs over the last few years [2-5], but much still remains to be understood and tested in terms of dynamic performance, controller performance, stability analysis, harmonic mitigation schemes, circulating current mitigation schemes especially for converters configured with a large number of modules, before this type of converter can be fully deployed in real time applications.The basic operation of MMC [1] and its internal dynamics [2] have been reported, but no explicit analytical expressions for the arm currents in terms of state space approach have been presented so far. State Space approach of MMC for the arm currents, circulating currents for their interaction with the arm voltages are a vital component for the understanding of the operation of the converter. Explicit expressions are very helpful to forecast the frequencies, the amplitudes, and the phase angles of the harmonic components present in legs of MMC. However, the multiple frequency components can vary by varying of the control signals, and different control schemes have been suggested in literature [4-8]. Due to the uneven voltage distribution in the arms of a phase, circulating currents starts to flow through the legs of the converter. The circulating currents consist of harmonics resulting in the deterioration of the system performance [7-9]. In order to control the circulating currents and mitigate the harmonics, in [6], a method was proposed where under the balanced voltage condition; the negative-sequence component of circulating currents in each arm rotates at double-line frequency. Therefore, a control method was proposed in each arm by transforming *a-c-b* sequence with a double line-frequency into a *d-q* sequence at the rotational reference frame. However, this method has the disadvantage of not being able to completely reduce circulating currents under unbalanced voltage conditions, because circulating currents also possess positive-sequence components and zero-sequence components besides negative-sequence components. In [2], a method was proposed so as to mitigate circulating currents by calculating the instantaneous power of each arm under unbalanced voltage conditions. This control technique has the disadvantage of inclusion of a double-line-frequency ripple in ac-side active power by controlling ac-side negative-sequence currents to zero under unbalanced voltage conditions. A control method was developed in [3] for circulating currents in *a-b-c* stationary frame, since circulating currents have positive-, negative-, and zero-sequence components under unbalanced voltage conditions. But, this method has the disadvantage of generating a phase delay because of its utilization of a high-pass filter to separate circulating currents; furthermore, it cannot improve the transient response occurring in the inner unbalanced currents and dc-link currents under unbalanced voltage conditions [7-9]. In [6] model predictive control (MPC) was used to control the circulating currents. However, this method has a disadvantage in the volume of the calculation required by the processor, which increases with an increase in the level of the MMC.

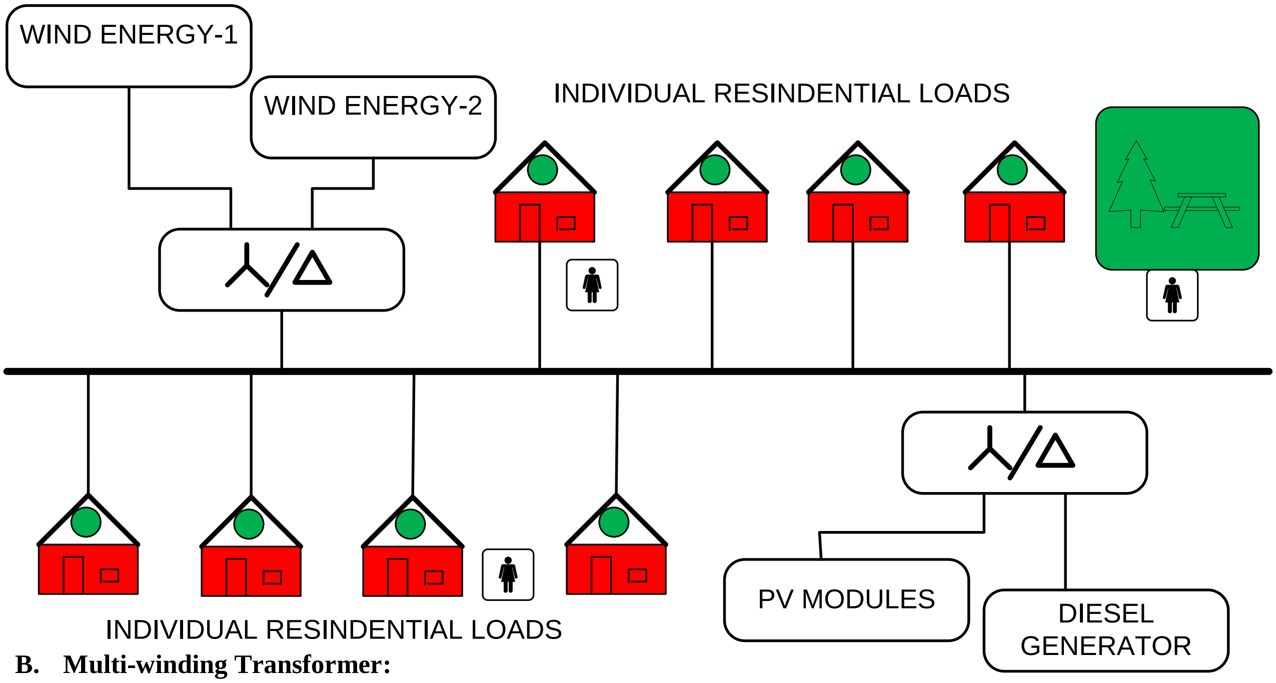


Fig.1.Basic schematic of micro grid

B. Multi-winding Transformer:

Multi winding transformer (MWT) is used for variety of applicationsin power electronics industry mainly for galvanic isolation. In this article MWT is used to interconnect the wind energy generating systems to micro grid. Multi winding transformer basically consists two 3-phase star windings in primary side and one 3-phase delta winding as secondary side. One of the star connected primary winding is connected to one of the two wind generators and other is connected to remain star winding at primary side.From the two wind energy systems, different voltage will be developed in their primary side and transferred to secondary side by the process of mutual induction. In the transformer all the coils with self-flux is denoted as $\emptyset_A, \emptyset_{B,}, \emptyset_C, \emptyset_{A^I}, \emptyset_{B^I}, \emptyset_{C^I}, \emptyset_P, \emptyset_Q, \emptyset_R$ and mutual flux linkages inductances A coil to all coils$\emptyset_{AB}, \emptyset_{AC}, \emptyset_{AA^I}, \emptyset_{AB^I}, \emptyset_{AC^I}, \emptyset_{AP}, \emptyset_{AQ}, \emptyset_{AR}$ similarly$B, C, A^I, B^I, C^I, P, Q, R$ as shown in fig.2.

Across each winding voltage expressed with flux linkages shown in below equations

$$V_A = N_A \frac{d}{dt}\left(\emptyset_m + \emptyset_A + \emptyset_{AB} + \emptyset_{AC} + \emptyset_{AA^I} + \emptyset_{AB^I} + \emptyset_{AC^I} + \emptyset_{AP} + \emptyset_{AQ} + \emptyset_{AR}\right) \quad (1)$$

$$V_B = N_B \frac{d}{dt}\left(\emptyset_m + \emptyset_B + \emptyset_{BA} + \emptyset_{BC} + \emptyset_{BA^I} + \emptyset_{BB^I} + \emptyset_{BC^I} + \emptyset_{BP} + \emptyset_{BQ} + \emptyset_{BR}\right) \quad (2)$$

$$V_C = N_C \frac{d}{dt}\left(\emptyset_m + \emptyset_C + \emptyset_{CA} + \emptyset_{CB} + \emptyset_{CA^I} + \emptyset_{CB^I} + \emptyset_{CC^I} + \emptyset_{CP} + \emptyset_{CQ} + \emptyset_{CR}\right) \quad (3)$$

$$V_{A^I} = N_{A^I} \frac{d}{dt}\left(\emptyset_m + \emptyset_{A^IA} + \emptyset_{A^IB} + \emptyset_{A^IC} + \emptyset_{A^I} + \emptyset_{A^IB^I} + \emptyset_{A^IC^I} + \emptyset_{A^IP} + \emptyset_{A^IQ} + \emptyset_{A^IR}\right) \quad (4)$$

$$V_{B^I} = N_{B^I} \frac{d}{dt}\left(\emptyset_m + \emptyset_{B^IA} + \emptyset_{B^IB} + \emptyset_{B^IC} + \emptyset_{B^I} + \emptyset_{B^IA^I} + \emptyset_{B^IC^I} + \emptyset_{B^IP} + \emptyset_{B^IQ} + \emptyset_{B^IR}\right) \quad (5)$$

$$V_{C^I} = N_{C^I} \frac{d}{dt}\left(\emptyset_m + \emptyset_{C^IA} + \emptyset_{C^IB} + \emptyset_{C^IC} + \emptyset_{C^I} + \emptyset_{C^IA^I} + \emptyset_{C^IB^I} + \emptyset_{C^IP} + \emptyset_{C^IQ} + \emptyset_{C^IR}\right) \quad (6)$$

$$V_P = N_P \frac{d}{dt}\left(\emptyset_m + \emptyset_P + \emptyset_{PA} + \emptyset_{PB} + \emptyset_{PC} + \emptyset_{PA^I} + \emptyset_{PB^I} + \emptyset_{PC^I} + \emptyset_{PQ} + \emptyset_{PR}\right) \quad (7)$$

$$V_Q = N_Q \frac{d}{dt}\left(\emptyset_m + \emptyset_Q + \emptyset_{QA} + \emptyset_{QB} + \emptyset_{QC} + \emptyset_{QA^I} + \emptyset_{QB^I} + \emptyset_{QC^I} + \emptyset_{QP} + \emptyset_{QR}\right) \tag{8}$$

$$V_R = N_R \frac{d}{dt}\left(\emptyset_m + \emptyset_R + \emptyset_{RA} + \emptyset_{RB} + \emptyset_{RC} + \emptyset_{RA^I} + \emptyset_{RB^I} + \emptyset_{RC^I} + \emptyset_{RP} + \emptyset_{RQ}\right) \tag{9}$$

As well as the transformer voltage and current relation expressed with inductances in the below equation.

$$\begin{bmatrix} V_A \\ V_B \\ V_C \\ V_{A^I} \\ V_{B^I} \\ V_{C^I} \\ V_P \\ V_Q \\ V_R \end{bmatrix} = \begin{bmatrix} L_{AA} & M_{AB} & M_{AC} & M_{AA^I} & M_{AB^I} & M_{AC^I} & M_{AP} & M_{AQ} & M_{AR} \\ M_{BA} & L_{BB} & M_{BC} & M_{BA^I} & M_{BB^I} & M_{BC^I} & M_{BP} & M_{BQ} & M_{BR} \\ M_{CA} & M_{CB} & L_{CC} & M_{CA^I} & M_{CB^I} & M_{CC^I} & M_{CP} & M_{CQ} & M_{CR} \\ M_{A^IA} & M_{A^IB} & M_{A^IC} & L_{A^IA^I} & M_{A^IB^I} & M_{A^IC^I} & M_{A^IP} & M_{A^IQ} & M_{A^IR} \\ M_{B^IA} & M_{B^IB} & M_{B^IC} & M_{B^IA^I} & L_{B^IB^I} & M_{B^IC^I} & M_{B^IP} & M_{B^IQ} & M_{B^IR} \\ M_{C^IA} & M_{C^IB} & M_{C^IC} & M_{C^IA^I} & M_{C^IB^I} & L_{C^IC^I} & M_{C^IP} & M_{C^IQ} & M_{C^IR} \\ M_{PA} & M_{PB} & M_{PC} & M_{PA^I} & M_{PB^I} & M_{PA^I} & L_{PP} & M_{PQ} & M_{PR} \\ M_{QA} & M_{QB} & M_{QC} & M_{QA^I} & M_{QB^I} & M_{QC^I} & M_{QP} & L_{QQ} & M_{QR} \\ M_{RA} & M_{RB} & M_{RC} & M_{RA^I} & M_{RB^I} & M_{RC^I} & M_{RP} & M_{RQ} & L_{RR} \end{bmatrix} \frac{d}{dt} \begin{bmatrix} I_A \\ I_B \\ I_C \\ I_{A^I} \\ I_{A^I} \\ I_{A^I} \\ I_P \\ I_Q \\ I_R \end{bmatrix} \tag{10}$$

II. System Investigated:

The basic proposed system consists of mainly two wind energy generating system which is shown in fig.2.The output of each generator is connected to the multi-winding transformer primary winding with a capacitor bank. The purpose of the capacitor bank is to compensate the reactive power obtained from the wind energy systems. Thus obtained output from the multi winding transformer is connected to the rectifier with necessary filter to eliminate the ripple content. Thus obtained 'dc' as acts as input to the inverter.In this article,it has been used MMC due to its excellent characteristics.Thus obtained 'ac' is controlled by the proposed voltage controller to maintain constant voltage and is shown in fig.3.In fig.2, it has been implementedwith various wind speeds. One is with constant incremental wind speed another is with variable speeds as shown in table.1 and table.2 respectively.

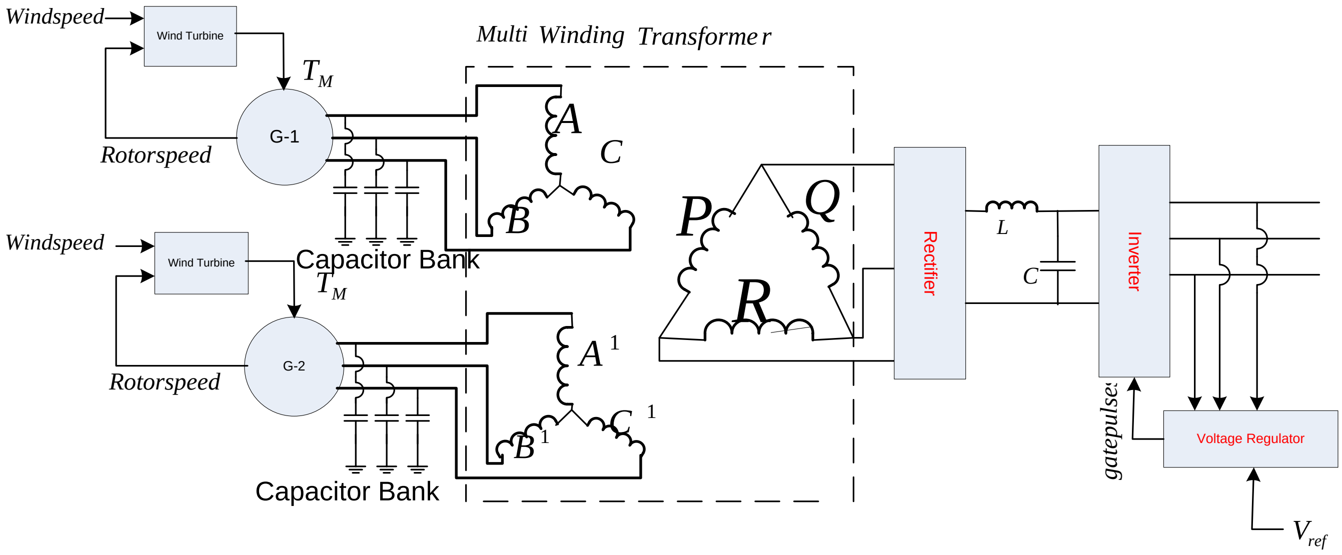


Fig.2. Basic block diagram of investigated system

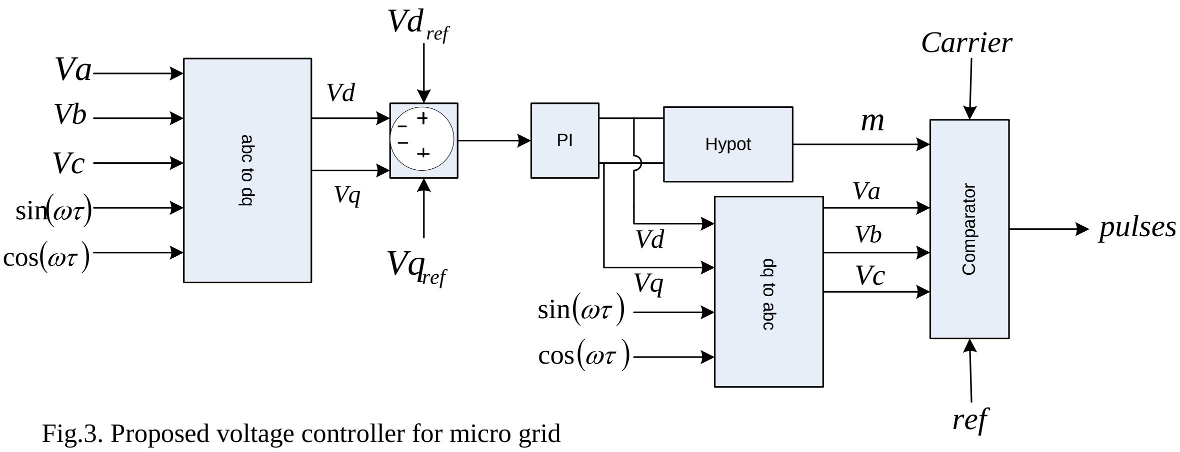


Fig.3. Proposed voltage controller for micro grid

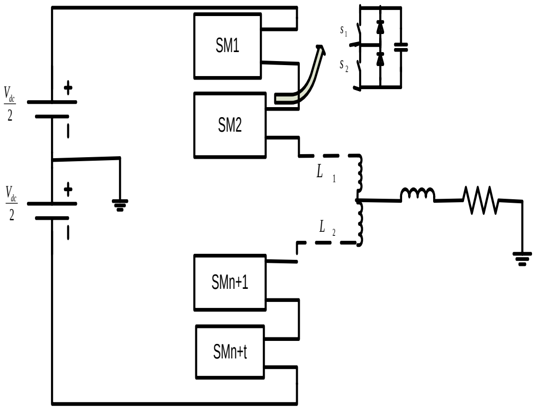


Fig.3. Basic block diagram of Modular Multi Level Converter

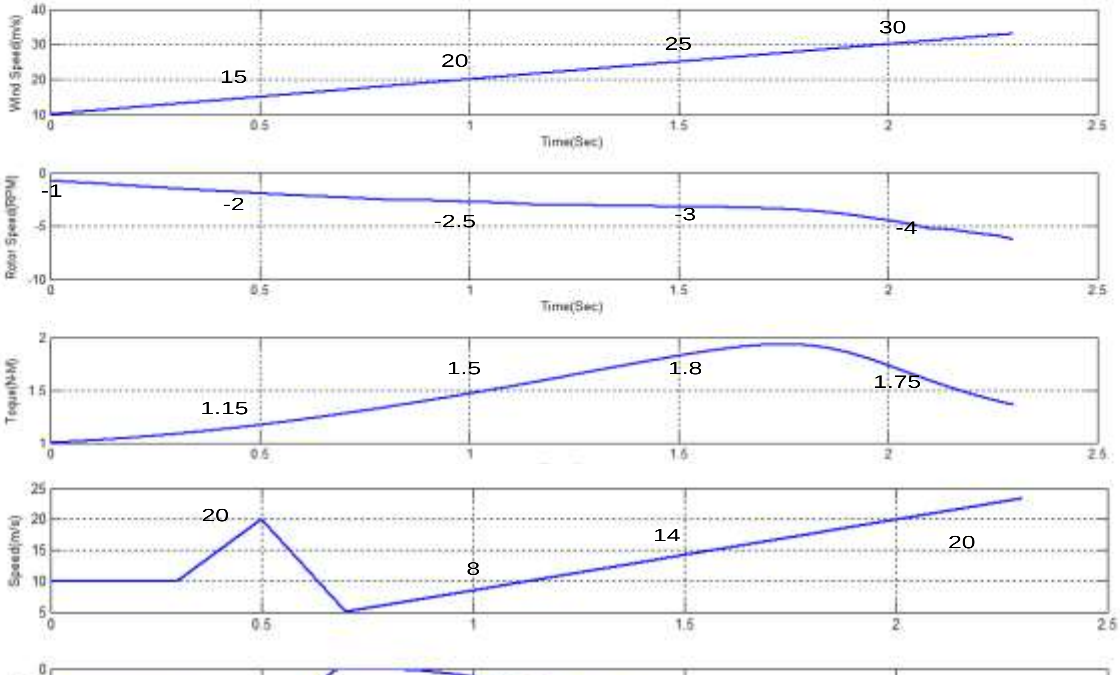


Fig.4: generator rotor speed and torque with varying wind speeds

Table.1 Wind generator characteristics at constant incremental speed

S.no	Mode	Time(sec)	Wind speed(m/s)	Rotor speed(rpm)	Torque(N/M)
1	At ramp wind speed	0	10	-1	1
2		0.5	15	-2	1.15
3		1	20	-2.5	1.5
4		1.5	25	-3	1.8
5		2	30	-4	1.75

Table.2 Wind generator characteristics at variable speed

s.no	Mode	Time(sec)	Wind speed(m/s)	Rotor speed(rpm)	Torque(N/M)
1	At variable wind speed	0	10	-0.9	1
2		0.5	20	-3.2	1.19
3		1	8	-0.2	1.21
4		1.5	14	-1.5	1.38
5		2	20	-2.5	1.6

Firstly it has been analyzed with the constant incremental wind speed in which,it has been considered with 0.5 Sec time step as shown in table.1.For incremental speed, torque generated by the system also varies and its graphical representation is shown in fig.4 top three waveforms.Then it has been analyzed with the variable wind speed in which, it has considered with 0.5 Sec time step as shown in table.2.For variable wind speed,torque generated by the system also varies and its graphical representation is shown in fig.4 bottom three waveforms.

Table.3 Asynchronous machine ratings

S.NO	PARAMETERS	VALUES
1	voltage (line-line)	440 volts
2	Frequency	50 Hz

3	Stator resistance (Rs)	0.016 ohm
4	Stator inductance(Lls)	0.06 H
5	Rotor resistance (Rr')	0.015 ohm
6	Rotor inductance (Llr')	0.06 H
7	Mutual inductance(Lm)	3.5 H

A. Introduction about MMC

The basic circuit topology is shown in fig 3. It is a three phase ‘N’ level MMC having ‘N’ sub modules in upper arm and ‘N’ sub modules in lower arm. This circuit mainly consists of an inductor having self-inductance L_1 and L_2, also called as arm inductors denoted by ‘L’ and these are present in each leg of the converter. Each module consists of sub-module switches S_1 and Sx_1 with their anti-parallel diodes D_1 and D_2respectively as shown in fig.3 . Sub-module switches S_1 and Sx_1 consist of a capacitor, connected in parallel and it is denoted as C_{u1}.The basic switching operations for some operating states has been shown in [1]. The top sub module switches in ‘R’ phase limb are considered as S_1,S_2,S_3…..$S_n$and the bottom four switches are considered as $S_{(n+1)}$,$S_{(n+2)}$,$S_{(n+3)}$…….S_{2n} of a single leg;Due to the uneven voltage distribution in the legs of MMC, circulating currents flows through the legs of MMC. Circulating currents (CC) ‘I_{cir}’ consists of current harmonics Here, an attempt is made to design their necessary controller to suppress the CC and its effect on MMC.

The instantaneous voltages across the capacitors are denoted as V_{c1}, V_{c2}, V_{c3}, V_{c4}..... V_{cn}.Also, the voltage distribution across the capacitors is considered as unequal for instance. The current flowing through the R phase top limb, bottom limb, circulating current and R phase currents are represented by ‘It_r’, ‘I_{lr}’, ‘I_{cir}’ and ‘I_r’ respectively. In order to find out voltage for the ‘R’ phase, KVL (Kirchoff’s Voltage Law) is applied to fig.3. Then the voltage across the R phase top limb ‘Vt_r’ and resistance R_{top}, is found out, keeping the following parameters in picture - Voltage for bottom limb is ‘V_{lr}’, resistance is R_{low}, circulating current is ‘I_{cir}’ with supply voltage, ‘V_{dc}’, ‘Vnt_r’ represents the voltage of limb ‘n’, and ’N’ represents the number of modules. Initially, it is assumed that the voltage across all sub module capacitors in upper arm and lower arm are equal and shown in eq.(11) and eq.(12) respectively.

$$V_{c1} = V_{c2} = V_{c3} \dots\dots.. = V_{cn} \qquad (11)$$

$$V_{c(n+1)} = V_{c(n+2)} = V_{c(n+3)} \dots\dots.. = V_{c2n} \qquad (12)$$

Under any switching condition, The sum of capacitors voltage for upper arm (V_{cu}) and lower arm (V_{cl}) is shown in eq. (13) and eq.(14) respectively; The voltage across the capacitor may change due to change in input voltage or load. Hence, it considered the sum of differential capacitor voltage for upper arm (ΔV_{cu}) and lower arm (ΔV_{cl}) is shown in the eq. (15) and eq.(16) respectively. The average voltage across the each upper arm sub-module and each lower arm sub-module are shown in eq.(17) and eq.(18).Where V_{DC} is the input DC voltage .

$$V_{cu} = V_{c1} + V_{c2} \dots\dots.. + V_{cn} \qquad (13)$$

$$V_{cl} = V_{c(n+1)} + V_{c(n+2)} \dots\dots.. + V_{c2n} \qquad (14)$$

$$\Delta V_{cu} = \Delta V_{c1} + \Delta V_{c2} \dots\dots.. + \Delta V_{cn} \qquad (15)$$

$$\Delta V_{cl} = \Delta V_{c(n+1)} + \Delta V_{c(n+2)} \dots\dots.. + \Delta V_{c2n} \qquad (16)$$

$$\frac{V_{cu}}{N} = \frac{V_{DC}+\Delta V_{cu}}{N} \qquad (17)$$

$$\frac{V_{cl}}{N} = \frac{V_{DC}+\Delta V_{cl}}{N} \qquad (18)$$

The circulating currents in the arm inductors consist of both DC (i_{dc}) and AC (i_{ac}) components as shown in eq.(19). These multiple frequency AC components are called harmonics and those are represented in eq.(19) which is a summation of all individual components.

$$I_{cir} = \frac{i_{dc}}{3} + i_{ac1} + i_{ac2} + i_{ac3} + \dots\dots i_{acn} \qquad (19)$$

In order to derive the disturbance voltage across the upper and lower arm sub module capacitors of a leg i.e. ΔV_{cu} and ΔV_{cl} , one should know the actual voltages for upper (V_{cu}) and lower arm (V_{cl}) which are shown in eq.(20).Where ‘i_u’ represents the current passing through the upper arm and ‘N_u’ represents the number of sub modules in upper arm of any leg.

$$V_{cu} = \frac{1}{C}\int i_u(t).N_u.dt \qquad (20)$$

III. Design of voltage controller

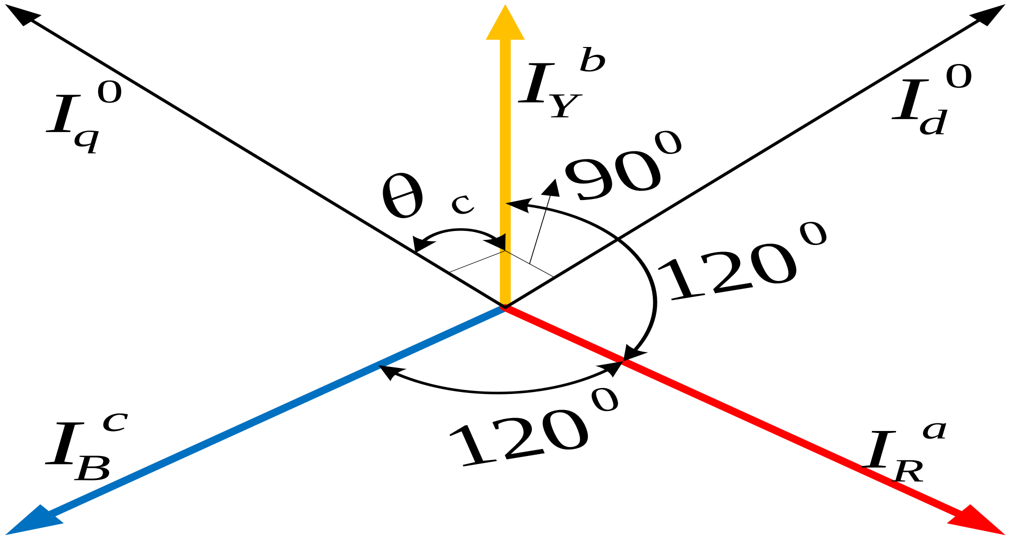
Primarily the voltage controller has been designed.Fig.5 shows the basic building block of voltage controller. It mainly sense the voltage from output terminals of MMC, considering that discrete PLL(Phase locked Loop) in which it does not contain any input but it will generate the sinusoidal pulses with defined frequency and phase angle for phases. The output voltage along with PLL has been passed through the park’s transformation (eq.(3.1),(3.2) and (3.3)) technique to transform form ***a-b-c*** form to ***d-q*** form for easy calculation.

$$V_d = \frac{2}{3}\left[V_a \sin(\omega t) + V_b \sin\left(\omega t - \frac{2\pi}{3}\right) + V_c \sin\left(\omega t + \frac{2\pi}{3}\right)\right] \qquad (3.1)$$

$$V_q = \frac{2}{3}\left[V_a \cos(\omega t) + V_b \cos\left(\omega t - \frac{2\pi}{3}\right) + V_c \cos\left(\omega t + \frac{2\pi}{3}\right)\right] \qquad (3.2)$$

$$V_0 = \frac{1}{3}\left[V_a + V_b + V_c\right] \qquad (3.3)$$

It performs the ***a-b-c*** to ***d-q-0*** transformation on a set of three phase angles. It computes the direct axis ‘v_d’, quadratic axis ‘v_q’, and zero sequence ‘v_0’ quantities in a two axis rotating reference frame as per the above equations (3.1) to (3.3).Where ‘ω’ is the rotating speed of the rotating reference frame in rad/sec.


$I_Y^{\,b}$
$I_q^{\,0}$
$I_d^{\,0}$
θ_c
90^0
120^0
120^0
$I_B^{\,c}$
$I_R^{\,a}$

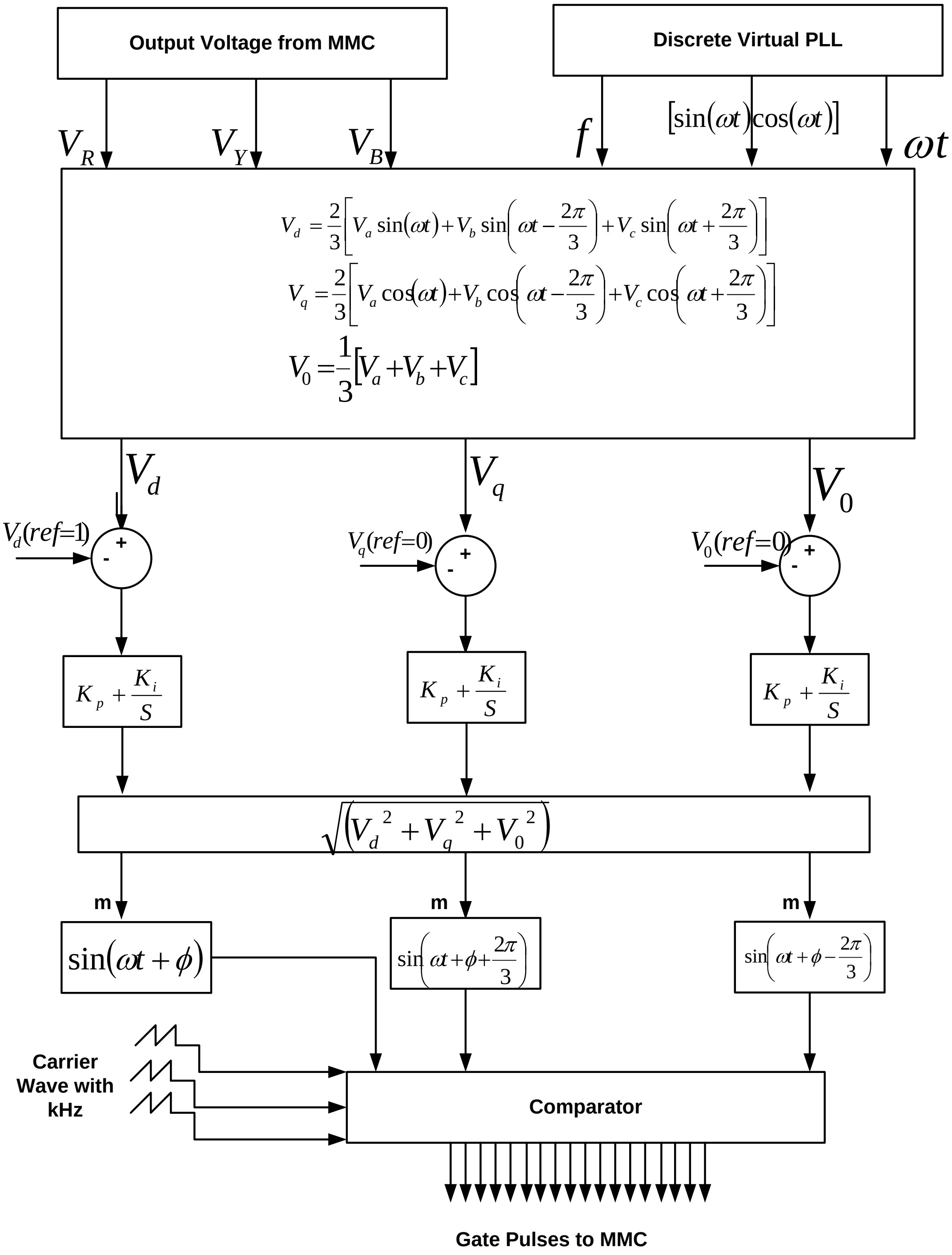


Fig.5 Block diagram of a voltage controller applied to MMC

The direct axis 'v_d', quadratic axis 'v_q', and zero sequence 'v_0' quantities in a two axis rotating reference frame is compared with their individual references as shown in fig.6.The obtained values should pass through the 'proportional-integral (PI)' controller to ensure the steady state error to be zero.

Once the steady state error is ensured, it needs to obtain the required modulation index (m) for the reference wave which is sinusoidal in this case. The hypotenuse of direct axis and quadratic axis will decides the modulation index (m) of the sinusoidal signal as shown in fig.6.

Fig.3.1 Block diagram of a voltage controller applied to MMC

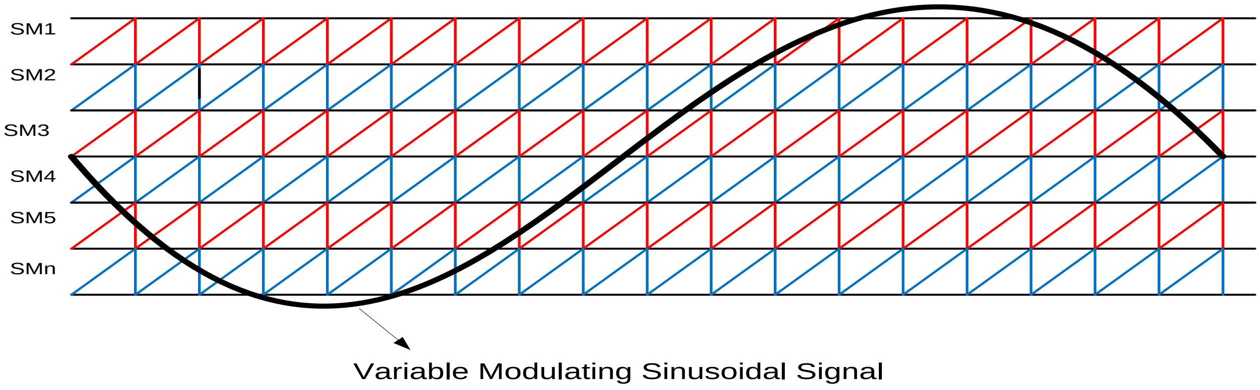


Fig.6 Variation of modulation index in reference wave of applied

Since, the system output voltage may consist of unwanted frequency components at sudden changes in load, hence it has been applied a new controller along with ‘PI’ as shown in eq.(3.4).

$$\frac{\frac{s}{\omega_c}+1}{\left(\frac{s}{k_i\omega_c}+1\right)} \qquad (3.4)$$

Hence the voltage controller will be deducted as

$$\left(k_p+\frac{k_i}{s}\right).\left(\frac{\frac{s}{\omega_c}+1}{\left(\frac{s}{k_i\omega_c}+1\right)}\right) \qquad (3.5)$$

Implementing the above deducted controller in fig(5) it can be redrawn as fig.(7).Where ω_c is the resonant frequency of the controller. In the above analysis, voltage controller has been designed by considering the output voltage as a reference. But in most of the cases, the output of MMC is not constant and the main source of voltage fluctuations in MMC is input DC bus voltage and modular capacitors. Here it assumed that input DC bus voltage as constant; hence the source of fluctuations is modular capacitors.

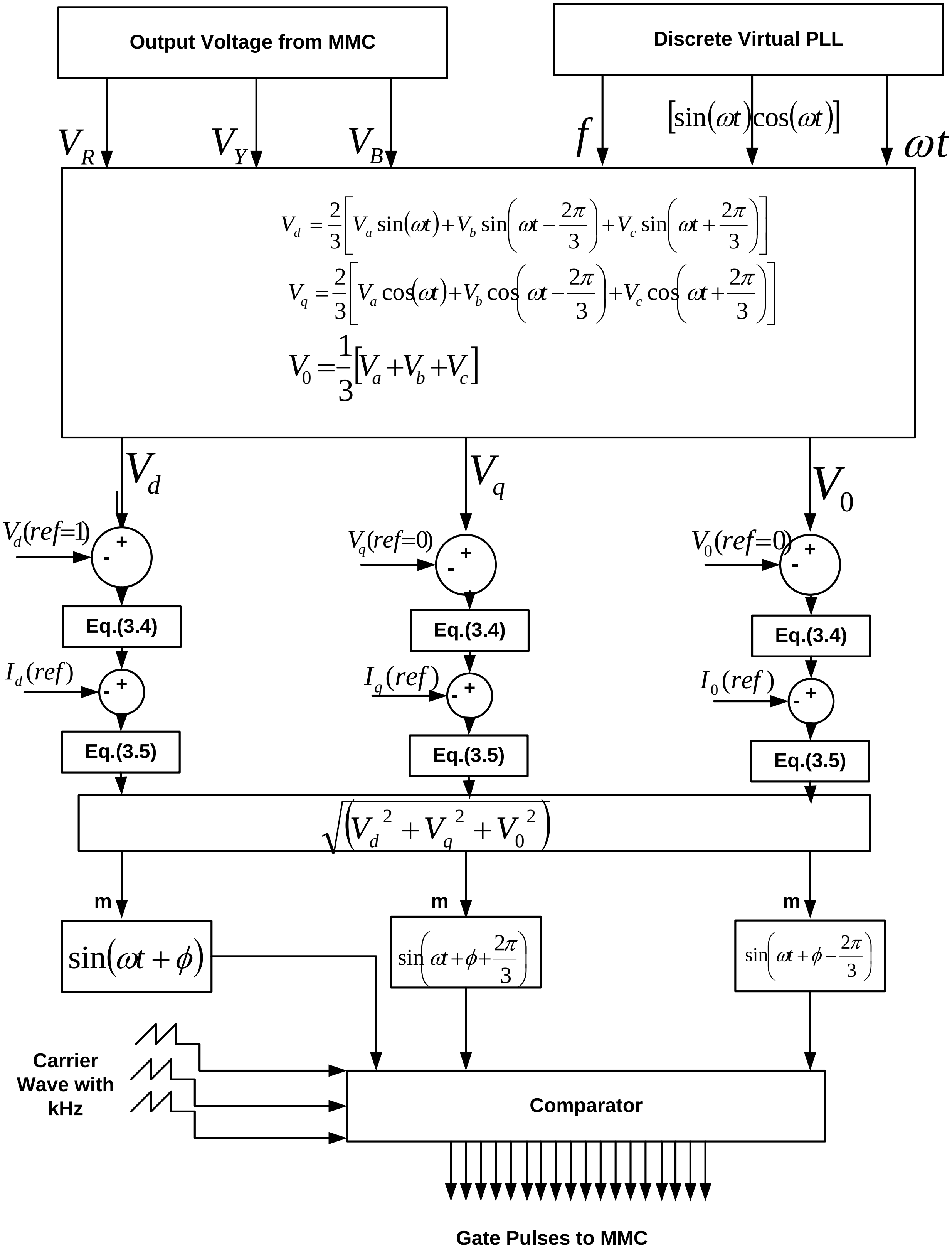


Fig.7 Block diagram of a modified voltage controller applied to MMC

IV. Simulation and Experimental Results

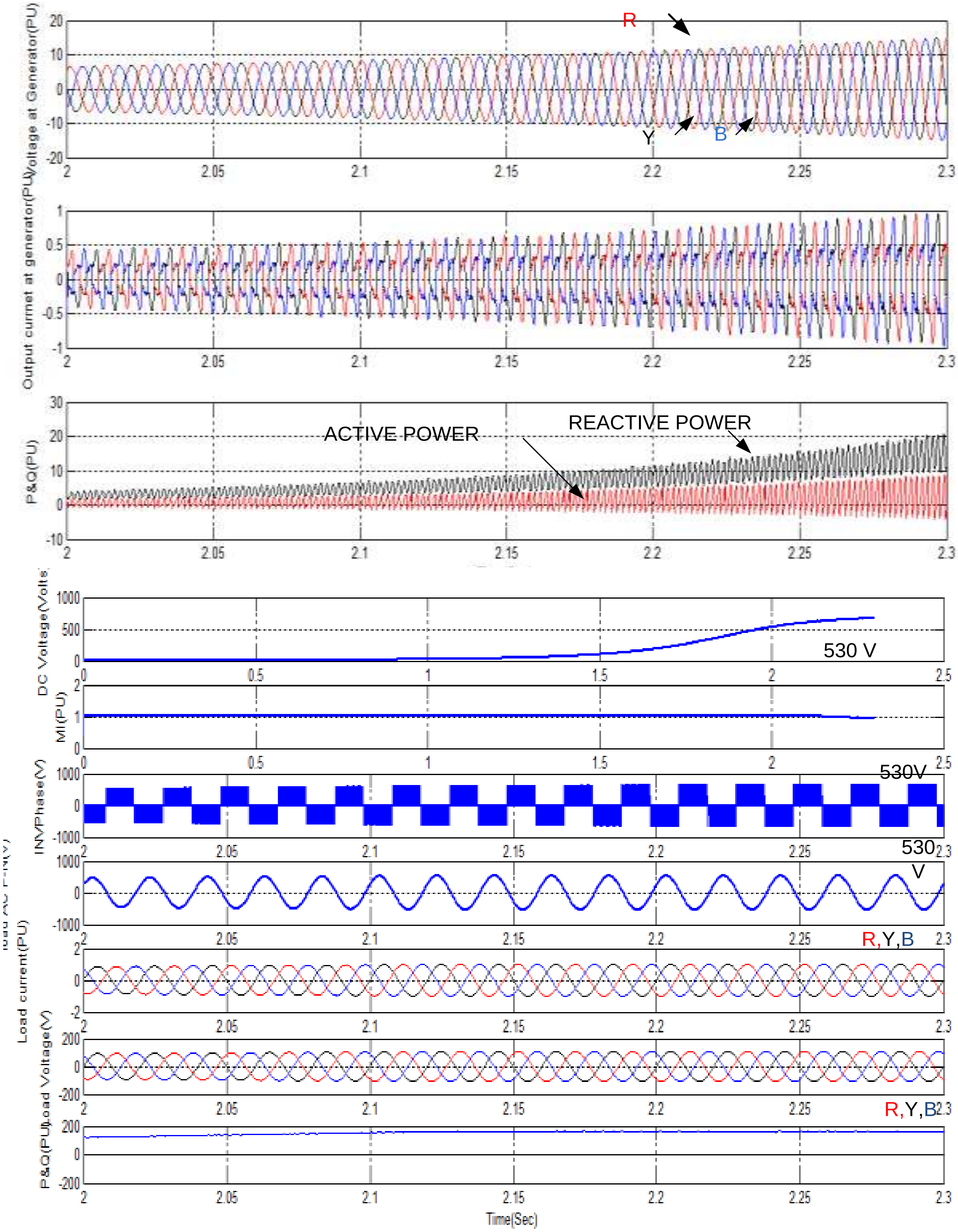


Fig.8 Simulation results for constant varying wind speed

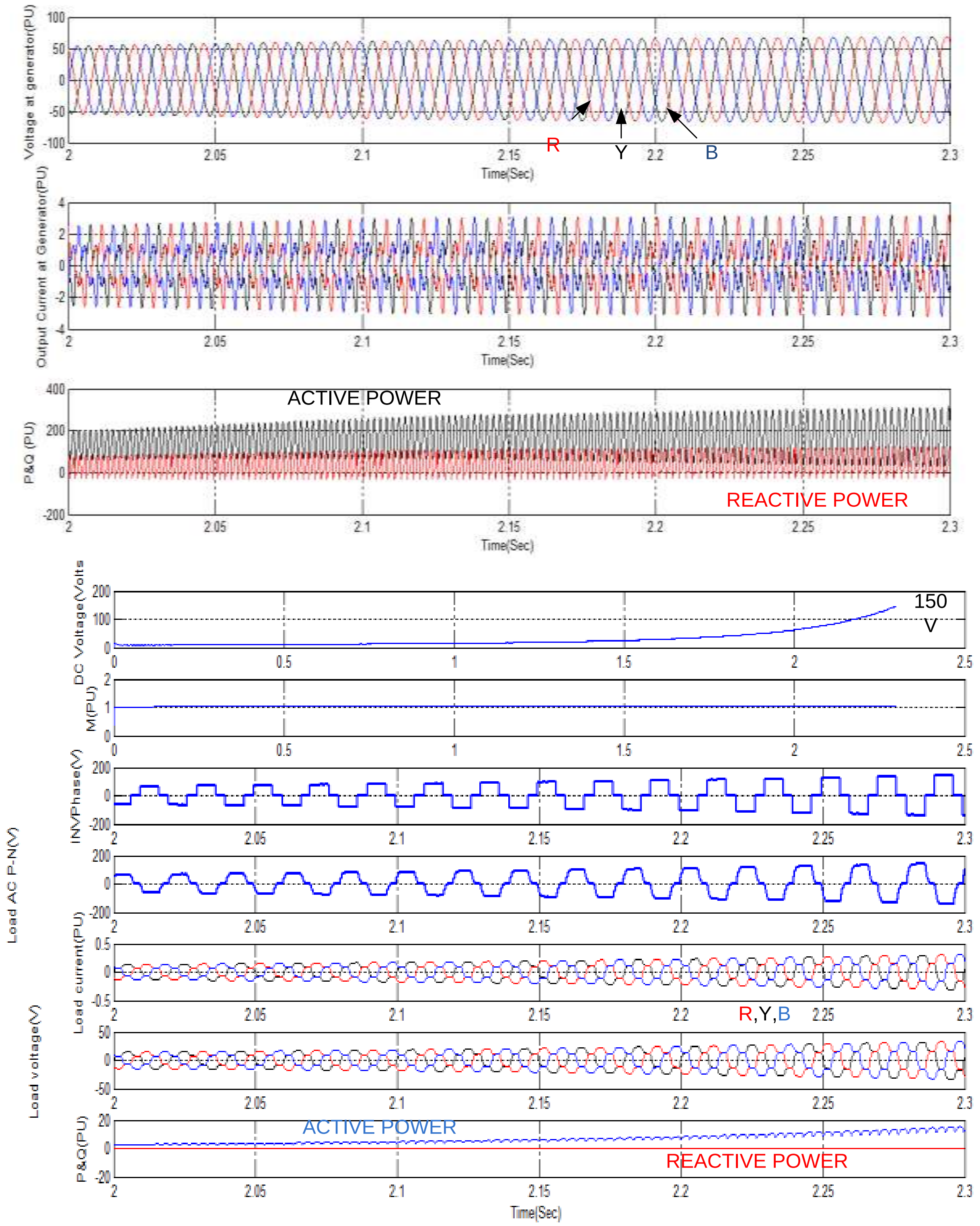


Fig.9 Simulation results for variable wind speed

The system has been simulated by using Matlab Simulink software for constant variable wind speed and variable wind speed which are shown in fig.8 and fig.9 respectively. The simulation results as per the sequence. Firstly, the three phase output voltage at the generator terminals with its current and showing its active and reactive power. The output 'dc' voltage obtained from the rectifier is shown with its inverter output for phase and line voltages. By comparing the generator output voltage and resultant output voltage at inverter, even though generator output is varying but its inverter voltage is constant which is shown in fig.8 . The same experiment has been repeated with the variable wind speed.The three phase output voltage at the generator terminals with its current and showing its active and reactive power. The output 'dc' voltage obtained from the rectifier is shown with its inverter output for phase and line voltages. By comparing the generator output voltage and resultant output voltage at inverter, even though generator output is varying but its inverter voltage is constant which is shown in fig.9.

Fig. 10 Experimental results for variable wind speed and constant incremental speed showing its constant voltages.

The system has been executed experimentally and its results have been shown in fig.10 which shows for any wind speed it maintains constant voltage across the terminals. In fig.10,top one shows the system output voltage without controller and where bottom one shows with the controller. Since the wave form is perfect sinusoidal, the THD content calculated as 1.3% which is far acceptable as per IEEE standards.

V. Conclusion

This article has been designed and implemented the new voltage controller with multi-winding transformer for micro grid applications. Firstly it has been implemented without controller and then with controller,the results have been comparedand conclusive remarks have been explored. MMC is implemented with an advanced voltage controller, tuned to control the voltage at its output. The system is examined for constant and variable wind speeds and their result has been analyzed. The proposed scheme shows its effectiveness by theoretical calculations, verified by simulation and experimental results.

VI. References:

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