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Implementation of 13-Level Inverter for Wind Applications

Jyothi munagalkar (PG Scholar)[1], Sanjeev kumar R A (Asst.Professor)[2]
Department of Electrical and Electronics[1,2]
PDA College of Engineering Kalaburgi, India[1,2]
jyotimunagalakar@gmail.com[1], sanju.san999@gmail.com[2]

Abstract- The implementation of a 13-level inverter with FACTS capability using modular multilevel converter technique wind energy application is presented. A current inverter with FACTS capability is positioned between the wind turbine and the distribution grid, which is same as existing wind energy inverter and is able to compensate reactive power transmitted to the distribution grid. This proposed inverter which is designed with distribution static synchronous compensators technology, which regulates the power of local feeder lines more over with this the new inverter will reduce the total cost of the system. The power angle and modulation index techniques are used to control the active and reactive power. The aim of this article is to transmit the active power to the distribution grid and to control the power factor of the feeder line. the simulation for an 13-level inverter has build through MATLAB/SIMULINK.

Index Terms- modular multilevel converter (MMC), flexible AC transmission system (FACTS), wind energy inverter (WIE)

1. INTRODUCTION

In an recent days the importance of PF is in distribution systems in widely increased, the non conventional form of energy can be easily converted to the conventional form of energy using PF devices in the form of voltage and frequency. A back to back converter in wind application is generally used in connection of generation to the distributive grid. A rectifier which convert an AC power to wind turbine into DC power , the inverter and transformer which convert the DC to the required AC power to the lines. With a great development in wind energy using advanced version of wind energy inverter which is an important issue with large number of small to large size wind turbine creating a huge problems for local utilities in terms of harmonics or PF problems. Incase of decrease the power losses and to increase the voltage regulation at the grid we require large PF in the power system. So compensating the reactive power across the load we can improve or increase the voltage regulation generally the capacitors banks are used to improve the PF issue in load side which may increase the over all cost of the system. The proposed inverter in this paper is outfitted with the D-STATCOM capability which is positioned between the turbine and distribution grid this proposed inerter which act as inverter with D-STSTCOM when there is no wind blowing to produce active power and when there is no wind it act as D-STATCOM only. Refer (1) Multilevel inverter technology has become evident use in high power medium voltage control. This paper give most relevant control of modulation types such as multilevel sinusoidal pulse width modulation, multilevel selective harmonic elimination and space vector modulation. Refer (2) among all multilevel topologies the recognized for STATCOM application for various reason. Refer (3) the modular multilevel converter which gives the description of MMC converter for HVDC applications. In

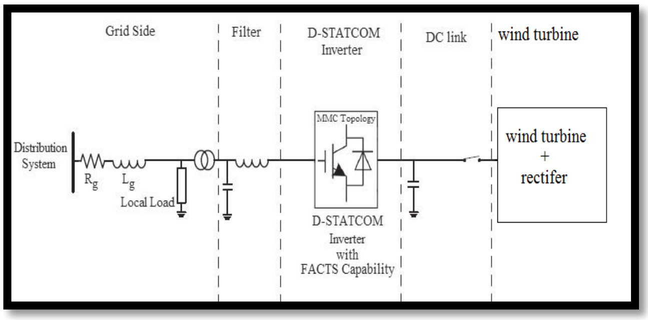

Fig 1 Configuration of proposed system

this paper we compares two different types of MMC, H-bride and full bridge sub modules. Refer (4) this paper which design and control of a D-STATCOM inverter for small to large size wind turbines to control the PF of the distributive grid the main drawback of this D-STATCOM inverter is that the output current which significantly fluctuate which is not compatible with IEEE standards.

2. MODULAR MULTILEVEL CONVERTER

MMC topology has grabbed a huge attention in a recent days. The MMC technique consist of several half bridge sub models per phase MMC contain of series connection of
2(n-1) basic sub model and two buffer inductors. Each sub model consist of two semiconductor switches , which operate in complementary mode, and one capacitor. The main advantage of MMC topology are: modular based on unique converter cell, easy realization of redundancy, and possibility

PF common dc bus. A single phase 13-level MMC inverter consists of 12 sub models in which 24 power switches, 12 capacitors and 1 buffer inductor.

3. PROPOSED SYSTEM

The proposed system mainly consist of three function ;Firstly to regulate the active and reactive power which transfer to the feeder line , secondly to maintain the voltage of sub model capacitors balanced , thirdly the design a required PWM techniques. Proposed inverter with FACTS capability : The MMC inverter which consists of several sub models and each sub model contain one floating capacitor and two power switch the fig 3.1 shows the 13 level MMC inverter

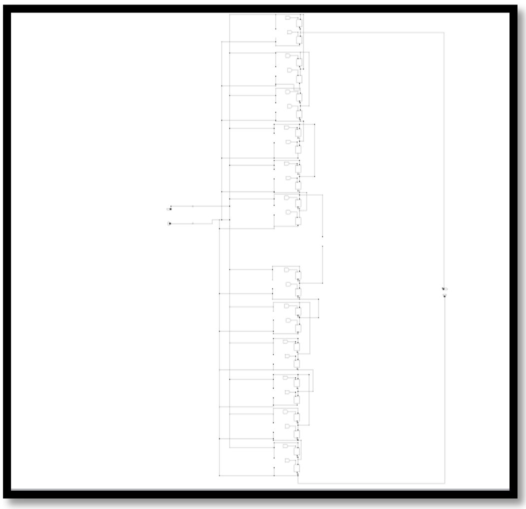

Fig 3.1:13-level inverter model

The proposed inverter presented in this paper utilize MMC topology. Replacing conventional inverters with this proposed inverter will eliminates need of separate capacitor bank or STATCOM device in order to fix the power factor of local distribution grids. The main application of the proposed inverter required a control of active and reactive power regardless of wind blowing .The system operate as a normal inverter when wind is blowing in addition to being able to met the target of power factor of distribution grid if there is no wind blowing the system act as D-STATCOM (capacitor bank)to regulate the power factor of distribution grid. The inverter is able to regulate the active and reactive power regardless of the input active power from the renewable energy source. The role of the proposed inverter is to provide utilities with distributive control of VAR compensation and power factor of local feeder lines. To enhance reactive power control of the proposed inverter, it is equipped with the D-STATCOM option which permits the inverter to convey reaction power independently from wind speed. The inverter is able to control the reactive and reactive power from the renewable energy source. The active and reactive power flow of the D-STATCOM inverter is as follows

$P_S = ME_S E_1 \sin\delta / X$

$Q_S = mE_S E_1 \cos\delta - E_1^2 / X$

Where E_S, is D-STATCOM inverter voltage, E_1 is line voltage , δ is power angle , m is modulation index , X is inductance between inverter and grid which is considered as output filter induction added to the transmission line inductance. The root mean square (RMS) voltage of the STATCOM (=inverter)is given as ES and is considered to be out of phase by an angle of δ to the RMS line voltage $E_{1.}$

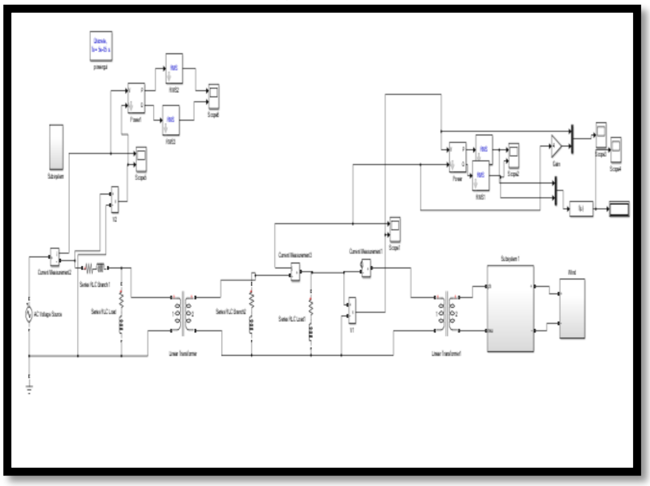

Fig3.2: simulation model of proposed system

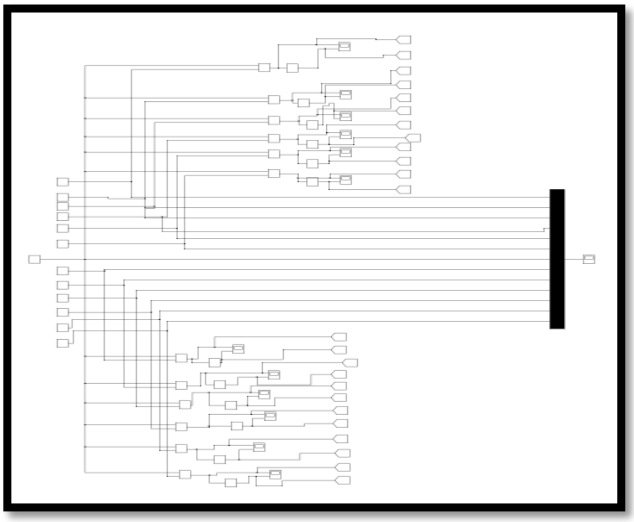

Fig 3.3: simulation of pulse generated by CPWM modulation technique

4. SIMULATION RESULTS

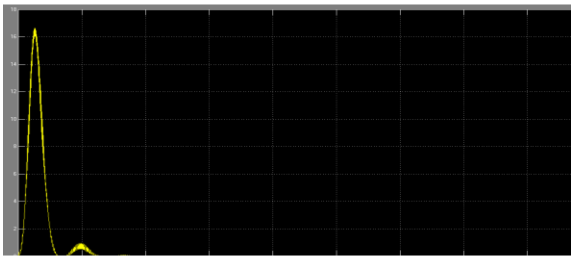

Fig 4.1 simulated output of wind

The simulation is 20sec long and contains many ramping and de-ramping of the wind turbine before t=01sec there is no wind power of the wind turbine .At t =0.1sec the input power of inverter is ramped, up to 18w in 0.6sec and then ramped down to 2w at1sec. The above fig 4.1 shows the output active power from the wind turbine.

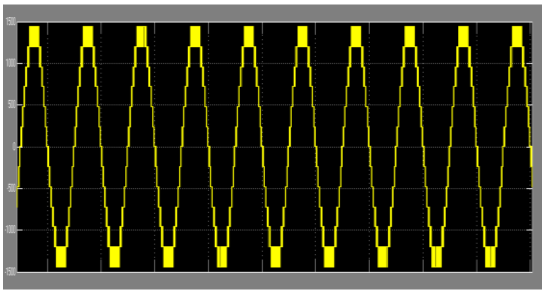

Fig 4.2 inverter output voltage without filter.

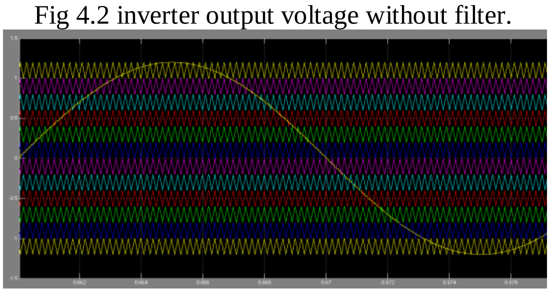

Fig 4.3 CPWM waveform for an 13 level MMC inverter

There is one reference wave and 12 carrier waves as shown in fig 4.3. By comparing these carrier signals with sinusoidal reference signal the gating pulses are generated. These gating pulses are given to the switches of an inverter.

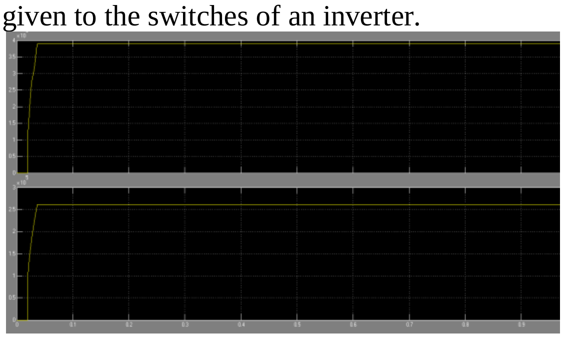

Fig 4.4 active and reactive power of grid

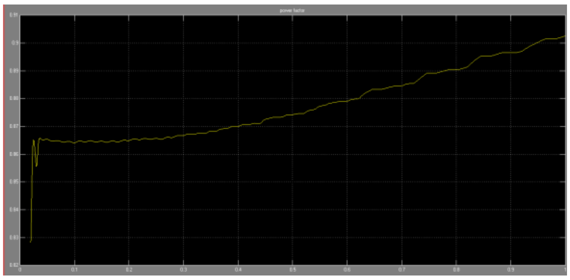

Fig 4.5 power factor of the system

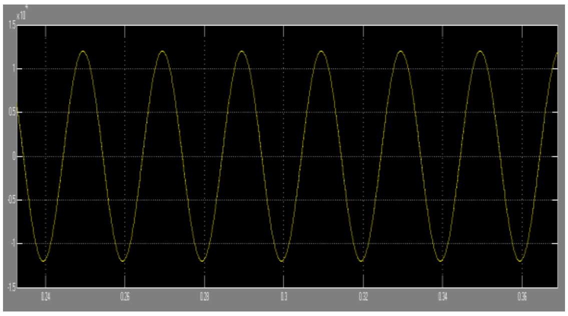

Fig 4.6 Output voltage of Grid

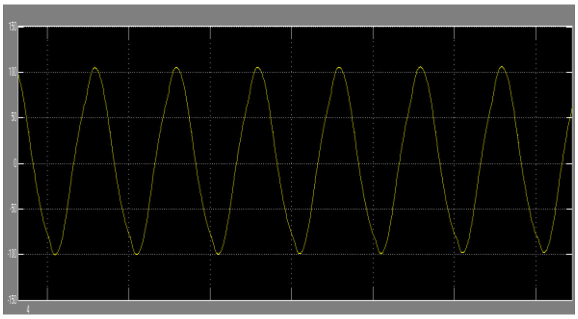

Fig 4.7 output current of grid

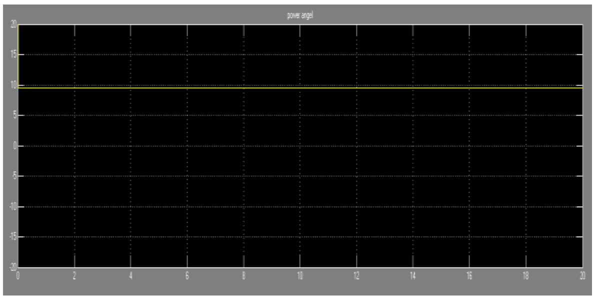

Fig 4.8 power angle

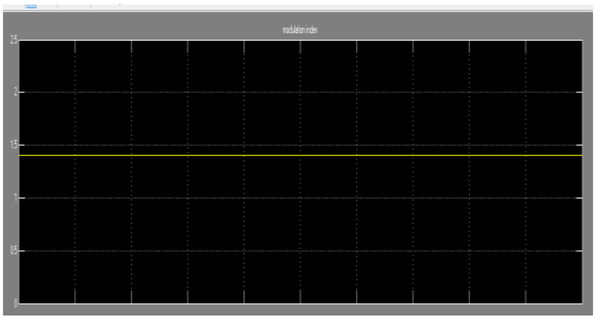

Fig 4.9 modulation index

Table 1 Operation for an 13- level MMC inverter

Voltage Level	Status	n(upper arms)	n(lower arms)	V_{out}
1	$V_r > v_{c1}, v_{c2}, v_{c3}, v_{c4}, v_{c5}, v_{c6}, v_{c7}, v_{c8}, v_{c9}, v_{c10}, v_{c11}, v_{c12}$	0	12	$6v_{dc}/12$
2	$V_r < v_{c1}$, $v_r \geq v_{c2}, v_{c3}, v_{c4}, v_{c5}, v_{c6}, v_{c7}, v_{c8}, v_{c9}, v_{c10}, v_{c11}, v_{c12}$	1	11	$5v_{dc}/12$
3	$V_r < v_{c1}, v_{c2}$ $V_r \geq v_{c3}, v_{c4}, v_{c5}, v_{c6}, v_{c7}, v_{c8}, v_{c9}, v_{c10}, v_{c11}, v_{c12}$	2	10	$4v_{dc}/12$
4	$V_r < v_{c1}, v_{c2}, v_{c3}$ $V_r \geq v_{c4}, v_{c5}, v_{c6}, v_{c7}, v_{c8}, v_{c9}, v_{c10}, v_{c11}, v_{c12}$	3	9	$3v_{dc}/12$
5	$V_r < v_{c1}, v_{c2}, v_{c3}, v_{c4}$ $V_r \geq v_{c5}, v_{c6}, v_{c7}, v_{c8}, v_{c9}, v_{c10}, v_{c11}, v_{c12}$	4	8	$2v_{dc}/12$
6	$V_r < v_{c1}, v_{c2}, v_{c3}, v_{c4}, v_{c5}$ $V_r \geq v_{c6}, v_{c7}, v_{c8}, v_{c9}, v_{c10}, v_{c11}, v_{c12}$	5	7	$1v_{dc}/12$
7	$v_r < v_{c1}, v_{c2}, v_{c3}, v_{c4}, v_{c5}, v_{c6}$, $v_r \geq v_{c7}, v_{c8}, v_{c9}, v_{c10}, v_{c11}, v_{c12}$	6	6	0
8	$V_r < v_{c1}, v_{c2}, v_{c3}, v_{c4}, v_{c5}, v_{c6}, v_{c7}$, vr≥vc8, $v_{c9}, v_{c10}, v_{c11}, v_{c12}$	7	5	$-1v_{dc}/12$
9	$V_r < v_{c1}, v_{c2}, v_{c3}, v_{c4}, v_{c5}, v_{c6}, v_{c7}, v_{c8}$ $V_r \geq v_{c9}, v_{c10}, v_{c11}, v_{c12}$	8	4	$-2v_{dc}/12$
10	$V_r < v_{c1}, v_{c2}, v_{c3}, v_{c4}, v_{c5}, v_{c6}, v_{c7}, v_{c8}, v_{c9}$ $V_r \geq v_{c10}, v_{c11}, v_{c12}$	9	3	$-3v_{dc}/12$
11	$V_r < v_{c1}, v_{c2}, v_{c3}, v_{c4}, v_{c5}, v_{c6}, v_{c7}, v_{c8}, v_{c9}, v_{c10}$, $v_r \geq v_{c11}, v_{c12}$	10	2	$-4v_{dc}/12$
12	$V_r < v_{c1}, v_{c2}, v_{c3}, v_{c4}, v_{c5}, v_{c6}, v_{c7}, v_{c8}, v_{c9}, v_{c10}, v_{c11}$ $v_r \geq v_{c12}$	11	1	$-5v_{dc}/12$
13	$V_r < v_{c1}, v_{c2}, v_{c3}, v_{c4}, v_{c5}, v_{c6}, v_{c7}, v_{c8}, v_{c9}, v_{c10}, v_{c11}, v_{c12}$	12	0	$-6v_{dc}/12$

5. CONCLUSION

In this article, the concept of proposed multilevel inverter with FACT'S technology for small o large size wind application is designed. This proposed inverter with FACTS technology is demonstrated in single unit without any addition cost .Replacing the regular wind energy with this proposed inverter will reduce the use of extra STATCOM device to control the PF of feeder lines. This new inverter will regulate active and reactive power by power angle and modulation index.

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