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A seven- Level Inverter with FACTS Capability for Distributed Systems

C.Sakthivel[1] *G.Abirami*[2*] *T.Santhiya*[3]
[1]*Department of Electrical and Electronics Engineering, JCT College of Engineering And Technology, Coimbatore, India.*
[2] *Department of Electrical and Electronics Engineering, SNS College of Technology, Coimbatore, India.*
**Corresponding Author email : abiganes18@gmail.com*

ABSTRACT

In this paper a single phase wind energy inverter with Flexible AC transmission system capability is implemented. The proposed inverter is placed between the wind turbine and the grid, same as a regular WEI, and is able to regulate active and reactive power transferred to the grid. This inverter is equipped with dynamic voltage restorer option in order to control the power factor of the local feeder lines. The goal of this project is to introduce new ways to increase the penetration of renewable energy systems into the distribution systems. This will encourage the utilities and customers to act not only as a consumer, but also as a supplier of energy. Moreover, using the new types of converters with FACTS capabilities will significantly reduce the total cost of the renewable energy applications. In this project, modular multilevel converter is used as the desired topology to meet all the requirements of a single-phase system total harmonic distortion, efficiency, and total cost of the system. The control strategy regulates the active and reactive power using power angle and modulation index, respectively. The function of the inverter is to transfer active power to the grid as well as keeping the PF of the local power lines constant at a target PF regardless of the incoming active power from the wind turbine.

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1. Introduction

The power electronic devices due to their inherent nonlinearity draw harmonic and reactive power from the supply. In three phase systems, they could also cause unbalance and draw excessive neutral currents. The injected harmonics, reactive power burden, unbalance, and excessive neutral currents cause low system efficiency and poor power factor. The use of the sophisticated equipment/loads at transmission and distribution level has increased considerably in recent years due to the development in the semiconductor device technology. The equipment needs clean power in order to function properly. At the same time, the switching operation of these devices generates current harmonics resulting in a polluted distribution system. The power-electronics-based devices have been used to overcome the major power quality problems.

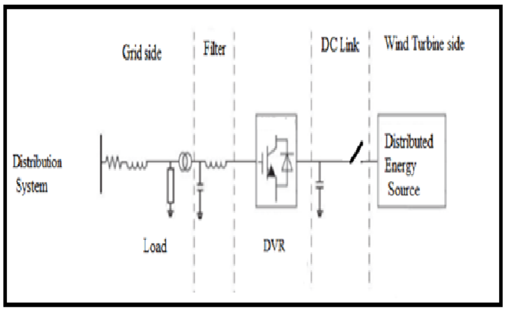

Fig. 1 Complete Configuration of the proposed inverter with FACTS capability.

All the non-linear loads draw highly distorted currents from the utility system, with their third harmonics component almost as large as the fundamental. The increasing use of non-linear loads, accompanied by an increase in associated problems concerns both electrical utilities and utility customer alike.

The power quality is improved by the use of implementation of DVR.DVR is one of the major custom power devices, capable of mitigating the effect of power quality problem. In existing system DSTATCOM is used. DSTATCOM can compensate almost all power quality problems such as: Voltage harmonics, voltage unbalance, Voltage flickers, voltage sags, voltage swells, Current harmonics, current unbalance, etc. Dynamic Voltage Restorer used for the voltage harmonic compensation and it gives a high impedance path to the harmonic currents voltage. In proposed system dynamic voltage restorer with eleven inverter is used and it has the capability of improving power quality at the point of installation and also on power distribution systems. The DVR, therefore, is expected to be one of the most powerful solutions to large capacity loads sensitive to supply voltage flicker/imbalance.

2. Modular Multilevel Converter

In this modeling and control of a 13 MW/20 KV MMC converter are used. Thus, objectives can be summarized:

- MMC operation principles: state of art and actual achievement
- MMC modeling: analysis of modeling approaches available
- Modeling Development and Simulation Verification of a

KW system

- Modeling Development and Simulation Verification of a MW system
- Control Strategies Analysis and Implementation: firstly on the KW system, then applied and verified on the MW system

New proposal for modeling and control modular construction, longer maintenance intervals and Multilevel topology instead offers advantages such as higher voltage levels, improved reliability.

A multilevel approach guarantees a reduction of output harmonics due to sinusoidal output voltages: thus grid filters become negligible, leading to system cost and complexity reduction. Like in many other engineering fields, modular and distributed systems are becoming the suggested topology to achieve modern projects requirements: this configuration ensure a more reliable operation, facilitates diagnosis, maintenance and reconfigurations of control system. Especially in fail safe situations, modular configuration allows control system to isolate the problem, drive the process in safe state easily.

MMC has gained increasing attention recently. A number of papers were published on the structure, control, and application of this topology , but none has suggested the use of that for inverter + D-STATCOM application. This topology consists of several half-bridge sub modules per each phase, which are connected in series. An n-level single phase MMC consists of a series connection of $2(n-1)$basic SMs and two buffer inductors. Each SM possesses two semiconductor switches, which operate in complementary mode, and one capacitor.

The exclusive structure of MMC becomes it an ideal candidate for medium to high voltageapplications such as wind energy applications. Moreover, this topology needs only one dc source, which is a key point for wind applications. MMC requires large capacitors which may increase the cost of the systems however; this problem is offset by the lack of need for any snubber circuit.

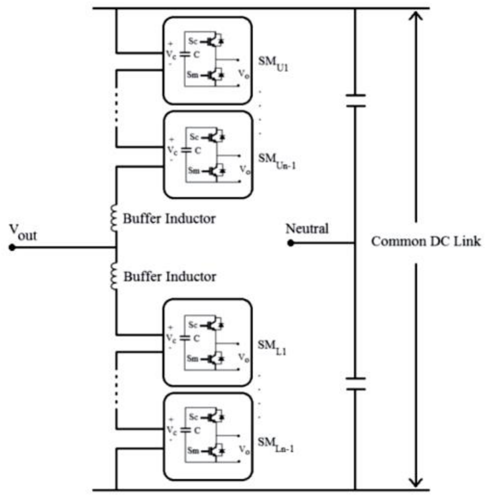

Figure.2. Structure of a Single Phase MMC Inverter

The main benefits of the MMC topology are: modular design based on identical converter cells, simple voltage scaling by a series connection of cells, simple realization of redundancy, and possibility of a common dc bus. Fig. 2.5shows the circuit configuration of a single-phase MMC and the structure of its SMs consisting of two power switches and a floating capacitor.

3. Proposed System

DVR is to inject a voltage of required magnitude and frequency. so that it can restore the load side voltage to the desired amplitude and waveform even when the source voltage is unbalanced. Among the power quality problems such as sags, swells, harmonics are the most severe disturbances. In order to overcome these problems the concept of custom power devices is introduced recently. One of those devices is the Dynamic Voltage Restorer, which is the most efficient and effective modern custom power device used in power distribution networks.

DVR is a recently proposed series connected solid state device that injects voltage into the system in order to regulate the load side voltage. It is normally installed in a distribution system between the supply and the critical load feeder at the point of common coupling.

Other than voltage sags and swells compensation, DVR can also added other features like: line voltage harmonics compensation, reduction of transients in voltage and fault current limitations. Power is injected and restored the load side voltage.

DVR is series compensation Flexible AC Transmission system device .Restore the load side voltage for its grid connection. Avoid the wastage of power in transmission line

A relatively new power converter structure, cascaded-inverters with separate DC sources is introduced here. This new converter can avoid extra clamping diodes or voltage balancing capacitors. Figure 3.3 shows the basic structure of the cascaded inverters with SDC for three phase configuration. Each SDC is associated with a single phase full bridge inverter. The AC terminal voltages of different level inverters are connected in series. The phase output voltage is synthesized by the sum of four inverter outputs. Each single-phase full bridge inverter can generate three level outputs, +Vdc, 0, and -Vdc. This is made possible by connecting the DC sources sequentially to the AC side via the four semiconductor power devices.

Maximum Power Point Tracking

Maximum power point tracking referred to as MPPT, an electronic system. MPPT is an essential part of PV system. It operates in a manner such that it optimizes the power generated by the power generated.

Since MPPT maximizes available power. As the output of PV system are dependent on the temperature radiation, and the load characteristic MPPT cannot deliver the output voltage perfectly. For this reason MPPT is required to be implementing in the PV system to maximize the PV array output voltage.

Necessity of Maximum Power Point Tracking

In the power versus voltage curve of a PV module there exists a single maxima of power, i.e. There exists a peak power corresponding to a particular voltage and current. The efficiency of the solar PV module is low about 13%. Since the module efficiency is low it is desirable to operate the module at the peak power point so that the maximum power can be delivered to the load under varying temperature and radiation conditions. This maximized power helps to improve the use of the solar PV module. A maximum power point tracker (MPPT) extracts maximum power from the PV module and transfers that power to the load. As an interfacing device DC/DC converter transfers this maximum power from the solar PV module to the load. By changing the duty cycles, the load impedance is varied and matched at the point of the peak power with the source so as to transfer the maximum power.

Different MPPT Techniques

There exist several techniques for tracking the MPP of a photovoltaic array. These techniques are commonly referred to as MPPTs, maximum power point trackers. The choice of the algorithm depends on the time complexity, the algorithm takes to track the MPP, implementation cost and the ease of implementation.

Some MPPT approaches are explained below.

1. Perturb and Observe
2. Incremental Conductance method
3. Fractional short circuit current
4. Fractional open circuit voltage
5. Fuzzy logic

Hill-Climbing Algorithm

Hill-climbing technique is the most popular MPPT methods due to their ease of implementation and good performance when the radiation is constant. The advantages of this method are the simplicity and low computational power they need. The shortcoming are also well known, oscillation around the MPP and they can get lost and track the MPP in the wrong direction during rapidly changing atmospheric conditions. This drawback is overcome by the neural network controller. The flow chart in the figure.3 gives complete description of MPPT and how current tracking happens in panel and the graphical form given in fig 4.

The P&O algorithm is also called "hill-climbing", but both refer to the same algorithm depending on how it is implemented. Hill-climbing involves a perturbation on the duty cycle of the power converter and P&O a perturbation in the

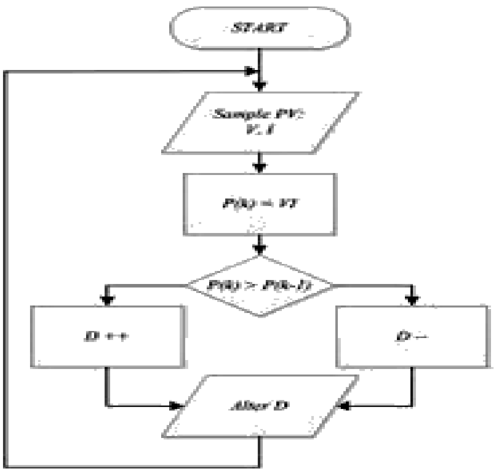

Fig.3. Flowchart for hill climbing technique operating voltage of the DC link between the array and the power converter

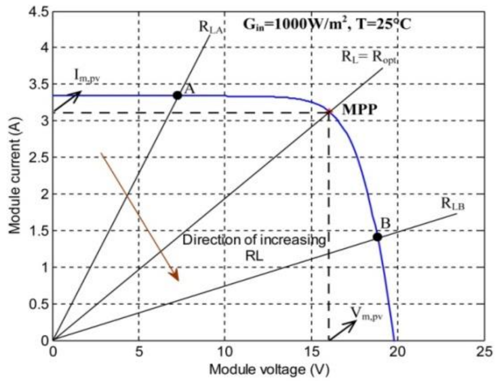

Fig.4. Graphical representation of MPPT

4. Simulation And Experimental Results

4.1 Input Waveform

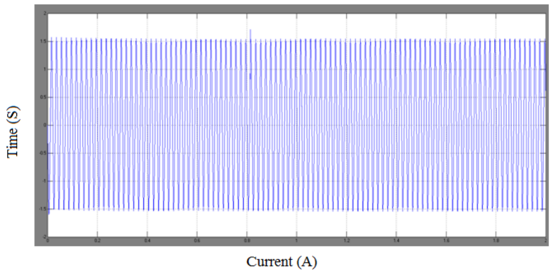

Fig.5 input waveform

The input waveform shown in Figure 5 is obtained by connecting a current source in series with the load. The output current are depend upon input.

4.2 Output Voltage of an Eleven level inverter

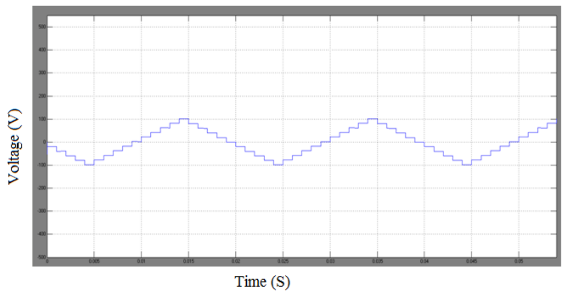

Fig. 6 Voltage levels

The DC supply is given to the inverter unit. A eleven level output is obtained. The voltage levels are shown in the Figure 6. The output voltage is measured using a voltage measurement unit connected and the output voltage is displayed via a scope.

4.3 Output Waveform with DVR

DVR output waveform for a proposed system as shown in Fig 7. The output is obtained by connecting the DVR in series with the system.The output is drawn between the amplidue and time period.The power quality problem such as sag,swell,interruption are eliminated.

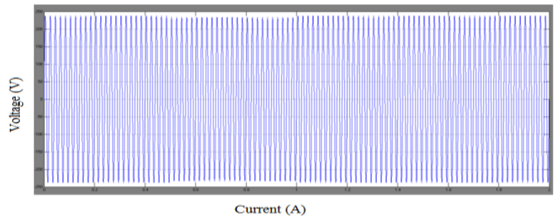

Fig.7 Output waveform for a proposed system

4.4 Output Waveform without DVR

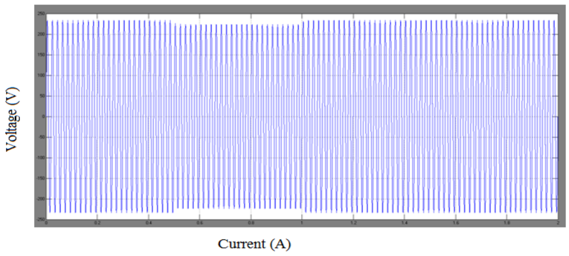

Fig. 8 Output waveform without DVR

Without DVR output waveform for a proposed system as shown in Fig 8.The without DVR output is obtained by removing the DVR in series with the system.The output is drawn between the amplidue and time period.The power quality problem such as sag,swell,interruption are presented in the system.

5. Conclusion

Multilevel inverter with FACTS capability for small to med-size wind installations is designed. The system demonstrates the application of a new inverter with FACTS capability in a single unit without any additional cost. The proposed topology is verified through the results obtained. The presented topology is very suitable for small to medium power applications .The active and reactive power is regulated for the improvement of power quality and also reduces the power quality problems. The MPPT algorithm is used to converts the output power of the wind turbine. The proposed controller system adjusts the active power by changing the power angle and reactive power is controllable by modulation index. Finally it should be noted that the power quality problems are reduced. A scheme needs to be developed and further investigated to make the inverter level increases.

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