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## Cascaded Two Level Electrical Converter-Based Multilevel STATCOM for High Power Utilization

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#### **Abstract:**

In this project, a simple static var compensating scheme using a cascaded two-level inverter-based multilevel inverter is proposed. The topology consists of two standard two-level inverters connected in cascade through open-end windings of a three-phase transformer. The dc-link voltages of the inverters are regulated at different levels to obtain four-level operation. The simulation study is carried out in MATLAB/SIMULINK to predict the performance of the proposed scheme under balanced and unbalanced supply-voltage conditions. A laboratory prototype is developed to validate the simulation results. The implemented control scheme is using the TMS320F28335 digital signal processor. Further, stability behavior of the topology is investigated. The dynamic model is developed and transfer functions are derived. The system behavior is analyzed for various operating conditions.

#### **Introduction:**

There has been an extensive growth and quick development in the exploitation of wind energy in recent years. The individual units can be of large capacity up to 2 MW, feeding into distribution network, particularly with customers connected in close proximity. Today, more than 28,000 wind generating turbines are successfully operating all over the world. In the fixed-speed wind turbine operation, all the fluctuation in the wind speed are transmitted as fluctuations in the mechanical torque, electrical power on the grid and leads to large voltage fluctuations. During the normal operation, wind turbine produces a continuous variable output power. L.Ramesh Associate Professor, Vidya Bharathi Institute of Technology, T.S, India.

These power variations are mainly caused by the effect of turbulence, wind shear, and tower-shadow and of control system in the power system.

#### **Problem Definition:**

Thus, the network needs to manage for such fluctuations. The power quality issues can be viewed with respect to the wind generation, transmission and distribution network, such as voltage sag, swells, flickers, harmonics etc. However the wind generator introduces disturbances into the distribution network. One of the simple methods of running a wind generating system is to use the induction generator connected directly to the grid system. The induction generator has inherent advantages of cost effectiveness and robustness. However; induction generators require reactive power for magnetization.

#### **System Operation:**

The shunt connected STATCOM with battery energy storage is connected with the interface of the induction generator and non-linear load at the PCC in the grid system. The STATCOM compensator output is varied according to the controlled strategy, so as to maintain the power quality norms in the grid system. The current control strategy is included in the control scheme that defines the functional operation of the STATCOM compensator in the power system. A single STATCOM using insulated gate bipolar transistor is proposed to have a reactive power support, to the induction generator and to the nonlinear load in the grid system. The main block diagram of the system operational scheme is shown in Fig. 3.2.



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Fig 1: system operational scheme in grid system

#### **Control scheme:**

The control scheme approach is based on injecting the currents into the grid using "bang-bang controller." The controller uses a hysteresis current controlled technique. Using such technique, the controller keeps the control system variable between boundaries of hysteresis area and gives correct switching signals for STATCOM operation.



Fig 2: Control system scheme

# Cascaded two-level inverter-based Multilevel STATCOM:

Fig.3 shows the power system model considered in this Fig. 2 shows the circuit topology of the cascaded two-level inverter-based multilevel STATCOM using standard two-level inverters.



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Fig 4: Cascaded two-level inverter-based multilevel STATCOM



Fig 5: Equivalent circuit of the cascaded two-level inverter-based multilevel STATCOM.

#### **Control Strategy:**

The control block diagram is shown in Fig. 6. The unit signals cos wt and sin wt are generated from the phase-locked loop (PLL) using three-phase supply voltages  $((v_a, v_b, v_c)[14])$ . The converter currents  $((i'_a, i'_b, i'_c))$  are transformed to the synchronous rotating reference frame using the unit signals. The switching frequency ripple in the converter current components is eliminated using a low-pass filter (LPF). From  $V_{dc1}^* + V_{dc2}^*$  and  $i_q^*$  loops, the controller generatesd -q axes reference voltages,e<sup>\*</sup><sub>d</sub>ande<sup>\*</sup><sub>a</sub>for the cascaded inverter. With these reference voltages, the inverter supplies the desired reactive current  $(i'_{a})$  and draws required active current (i'd) regulate total dclink voltage( $V_{dc1}^* + V_{dc2}^*$ ). However, this will not ensure that individual dc-link voltages are controlled at their respective reference values. Hence, additional control is required to regulate individual dc-link voltages of the inverters.

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#### **Reactive Power Control:**

In this case, reactive power is directly injected into the grid by setting the reference reactive current component  $i_q^*$  at a particular value. Initially, is set at 0.5 p.u. At t= 2.0 s, is  $i_q^*$  changed to 0.5 p.u. Fig. 7(a) shows the source voltage and converter current of the phase. Fig. 7(b) shows the dc-link voltages of two inverters. From the figure, it can be seen that the dc-link voltages of the inverters are regulated at their respective.



Fig 7: Reactive power control. (a) Source voltage and inverter current

#### (b) DC-link voltages of two inverters:

Reference values when the STAT Commode is changed from capacitive to inductive. Moreover, the dc-link voltage of inverter 2 attains its reference value faster compared to that of inverter 1 as discussed in Section II.

#### Load Compensation:

In this case, the STATCOM compensates the reactive power of the load. Initially, STATCOM is supplying a current of 0.5 p.u. At t= 2.0 s, the load current is increased so that STATCOM supplies its rated current of 1 p.u. Fig. 8(a) shows source voltage and converter current, while Fig. 8(b) shows the dc-link voltages of two inverters. The dc-link voltages are maintained at their respective reference values when the operating conditions are changed.



Fig 8: Load compensation. (a) Source voltage and inverter current.

#### (b) DC-link voltages of two inverters Operation during the Fault Condition

In this case, a single-phase-to-ground fault is created at t=1.2 s, on the phase of the HV side of the 33/11kVtransformer. The fault is cleared after 200 ms. Fig. 9(a) shows voltages across the LV side of the 33/11kV transformer. Fig. 9(b) and (c) shows the - axes components of negative-sequence current of the converter. These currents are regulated at zero during the fault condition.



Fig 9: Operation during fault. (a) Grid voltages on the LV side of the transformer.(b) -axis negativesequence current component. (c) -axis negativesequence current component.

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SIMULATION RESULTS STATCOM Reactive



#### **OUT PUTS**



Fig.11:Source output at reactive condition



Fig12:statcom output at reactive condition



Fig 13:vdc2 output at reactive condition



#### Fig14: vdc3 output at reactive condition STATCOM fault





Fig 16: source output at fault condition



Fig 17:stat com output at faultcondition



Fig 18:vdc2 output at fault condition



Fig19: vdc3 at fault condition

#### 5.3STATCOM load com



Fig 20: stat com load com

Fig 15:statcom fault

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#### **OUTPUT:**







Fig 22: stat com output at load com



Fig 23:vdc2 output at load com





#### **CONCLUSION:**

The paper presents the STATCOM-based control scheme for power quality improvement in grid connected wind generating system and with non linear load.

The power quality issues and its consequences on the consumer and electric utility are presented. The operation of the control system developed for the STATCOM-BESS in MATLAB/SIMULINK for maintaining the power quality is simulated. It has a capability to cancel out the harmonic parts of the load current. It maintains the source voltage and current in-phase and support the reactive power demand for the wind generator and load at PCC in the grid system, thus it gives an opportunity to enhance the utilization factor of transmission line. The integrated wind generation and STATCOM with BESS have shown the outstanding performance. Thus the proposed scheme in the grid connected system fulfills the power quality norms as per the IEC standard 61400-21.

#### **Future Enhancement:**

Simple static var compensating scheme using a cascaded two-level inverter-based multilevel inverter is proposed. The topology consists of two standard two-level inverters connected in cascade through open-end windings of a three-phase transformer. The dc-link voltages of the inverters are regulated at different levels to obtain four-level operation. The simulation study is carried out in MATLAB/SIMULINK to predict the performance of the proposed scheme under balanced and unbalanced supply-voltage conditions. A laboratory prototype is developed to validate the simulation results. The control scheme is implemented using the TMS320F28335 digital signal processor. Further, stability behavior of the topology is investigated. The dynamic model is developed and transfer functions are derived. The system behavior is analyzed for various operating conditions.

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