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Integrating the Solar and Wind Energy System Using Solid State Transformer

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Abstract

In this project a solid state transformer is used for integrating energy generated from solar and wind source and the resultant energy is supplied to load, instead of ordinary step up transformer solid state transformer is used. The proposed configuration meets latest grid code demand of wind turbine during fault condition. Based on the grid code demand, the Grid Interfacing Converter (GIC) has supplies reactive current during the fault condition. The fault is observed by perceiving positive sequence voltage magnitude and it is active in both types of fault conditions like symmetrical and unsymmetrical. The fault will exist for few milliseconds (ms) and the reactive current is added by GIC.

The turbine does not allow any variation in operating condition. The Solid State Transformer (SST) provides improved operation and performance when compared with a conventional transformer. Renewable source of energy is demand of the hour and hence the hybrid systemof solar and wind source helps in efficient use of renewable energy. When the wind energy generation is not reaches the rated value, this hybrid system has the ability to provide reactive power to the grid.

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I. INTRODUCTION

The energy generated by a source is transmitted and fed to load. The component that aids in transmitting power from source to load is transformer. To have a efficient transfer of energy solid state transformer is used and to meet increasing demand of energy renewable source of energy is used. Reactive current is generated when a fault is detected.

II. EXISTING SYSTEM

SST is designed as a power electronic device for the applications such as locomotives/traction, wind/solar farm, smart grid and charge station for reducing the weight and volume of the system in place of low frequency transformers. The earlier version of SST is designed only the consideration of theadvantage of reducing volume and weight. The SST interfaced wind energy systems focussed on their integrated active power transfer, voltage-conversion functions and reactive power compensation capability. However, a complete analysis on fault constrainsthroughout requirement and reactive power support has not been conducted in this system.

III. PROPOSED SYSTEM

SST is composed of power electronic device and it performs same function of a transformer but with better voltage regulation, increased efficiency and enhanced reactive power compensation. The solid state transformer can have more than one input source. The Wind Energy Conversion System (WECS) with Doubly Fed Induction Generator (DFIG) configuration has the rotor terminals of the machine are connected through back to back converters and the stator terminals are connected directly to the grid.

IV. DESCRIPTION

Compared with the traditional transformer, the fundamental reason for the usage of solid state transformer is to attain the voltage transformation by medium to high frequency isolation and also to decrease weight and volume requirements. The purpose of using renewable energy source is to meet the increasing demand of energy. The proposed system is a flexible type of system with reduced volume and weight.

By adding or drawing the active power from rotor, the Rotor Side Convertor (RSC) permits for variable speed operation of the machine. The DC link can be maintained using GSC by provide the active power from the grid to rotor or vice versa. The step up transformer T1 is a connecting part between the grid and DFIG system. Three stage SST configurations as shown in Figure 1.1 where itconnects to the distribution load from the grid. The fully controlled three phase converter named Conv - 1 is connected to the high voltage grid of 11-33 kV. The high voltage DC bus can be maintained by drawing real power from the grid.

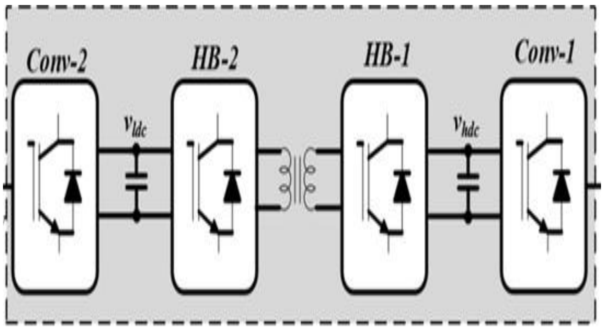

Figure 1.1 Representation of SST

Half bridge converter (HB-1) is used to convert the high voltage DC to high frequency AC voltage and this AC voltage will be stepped down using a high frequency transformer which is in smaller in size. This high frequency transformer maintains the galvanic isolation between the load and grid.

The low voltage AC is converted into low voltage DC voltage by using the second half bridge converter (HB-2). This DC bus helps conv-2 by producing a controlled three phase voltage and it is used to maintain the single phase or three phase supply voltage to the load.

This configuration thus executes the function of a regular transformer andpermits the bi-directional power flow using thearray of power electronics devices.The voltage profile can be improved by SST at the terminals. The solar and wind energy source can be integrated using SST is shown in the Figure 1.2. It shows the block diagram of the proposed model.

V. BLOCK DIAGRAM

Rotor Side Control (RSC):

The variable speed operation of DFIG by enabling the generator to work in any of the desired mode is ensured by the Rotor Side Control. The total power generated is partially discharged through RSC in case of sub synchronous mode of operation. The active power will be injected into the rotor by RSC under sub synchronous mode of operation

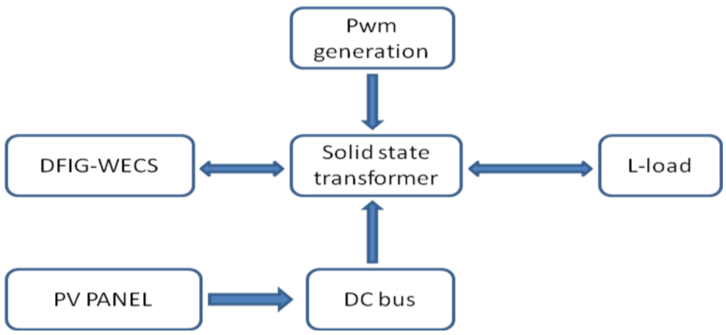

Figure 1.2 Block diagram of the proposed system.

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Machine interface converter (MIC):

Machine interface converter is a connector between the low voltage outputs in the machine to the high frequency stage and it is a first stage of SST.The low voltage DC bus is connected to MIC and it is used to consume the generated power at the stator terminal of the machine.

High frequency stage:

The low voltage DC bus voltage is converted into high voltage DC by high frequency stage. The high frequency AC voltage is converted from DC voltageby two half bridge converters. Power is delivered by offering a phase shift between the ACvoltages of the two converters connected together by a high frequency transformer. The main aim of high frequency stage transformer in the proposed configuration is to sustain the low voltage DC bus voltage at constant level

Grid Interfacing Converter (GIC):

This converter places a very essential role in the proposed system. GIC is controlled differently during fault condition when compared to the control of other converters. When fault occurs GIC injects current into the grid and the fault is rectified. If the wind source is insufficient reactive power is injected by GIC.

CIRCUIT DIAGRAM

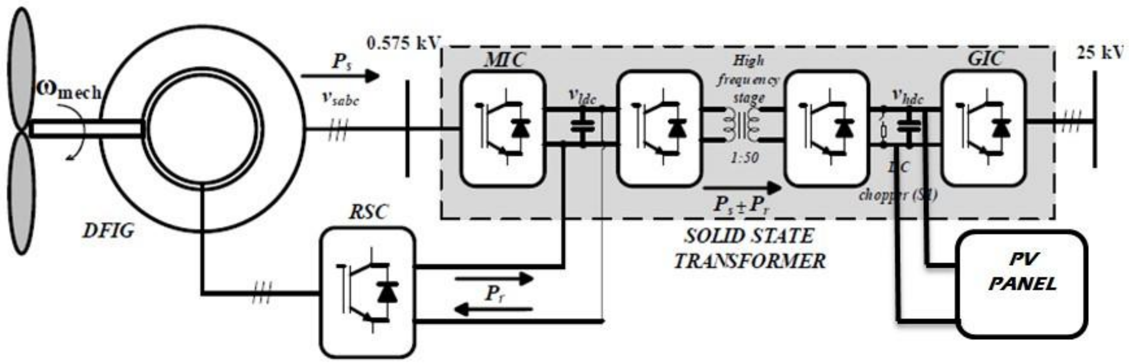

Figure 1.3 Proposed models with integrated energy source.

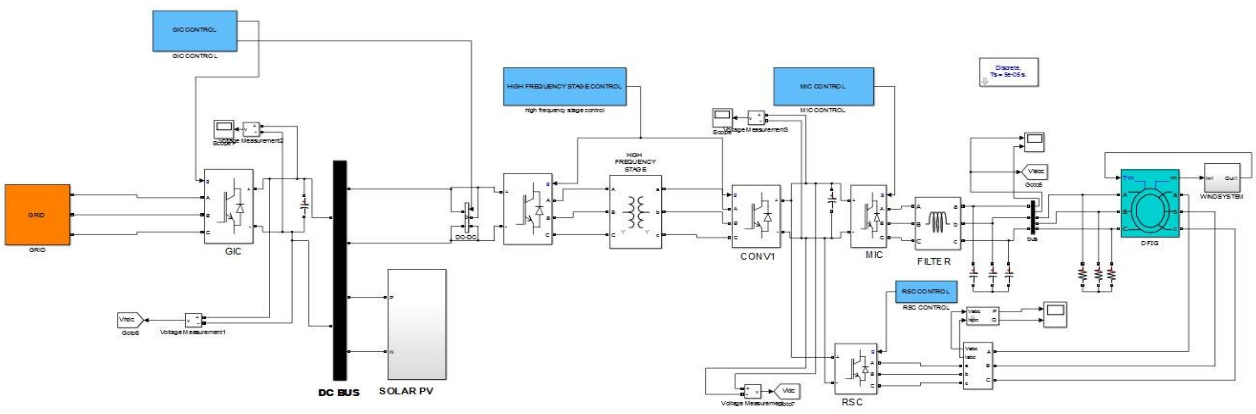

Figure 1.4 Circuit diagram of proposed system

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VI. WORKING OF PROPOSED MODEL

The Solid State Transformer (SST) attains voltage conversion through thearray of power electronics devices while offering multiple advantages such as, fault tolerant feature, improved power quality and smaller size where it connects the distribution load to the grid. The fully controlled three phase converter named Conv - 1 is connected to the high voltage grid of 11-33 kV. The high voltage DC bus can be maintained by drawing real power from the grid.

Half bridge converter (HB-1) is used to convert the high voltage DC to high frequency AC voltage and this AC voltage will be stepped down using a high frequency transformer which is in smaller in size. This high frequency transformer maintains the galvanic isolation between the load and grid.The low voltage AC is converted into low voltage DC voltage by using the second half bridge converter (HB-2). This DC bus helps conv-2 by producing a controlled three phase voltage and it is used to maintain the single phase or three phase supply voltage to the load.

This configuration thus executes the function of a regular transformer and permits the bi-directional power flow using thearray of power electronics devices.

Figure 1.4 shows the circuit diagram of the proposed system in MATLAB software the energy generated from wind source and solar energy is integrated using a solid state transformer. Symmetrical fault is introduced in the grid and it is being rectified using the proposed system. A precise model of proposed configuration is designed using the SIMULINK and SimPowerSystem toolbox in MATLAB. The conduction of proposed system is analyzed under different operating condition

VII. SIMULATION RESULTS

The wind source configured in the proposed system generates voltage of 3000 volts and the generated voltage is transmitted using the solid state transformer and the output of 2.5 kV is delivered from the solid state transformer. The aim of GIC is to assure that the active power developed by wind energy systemunder normal mode of operation. The additional function performed by GIC is providing reactive power support during low wind speed.

Performance of the proposed configuration under normal conditionStator voltage and current

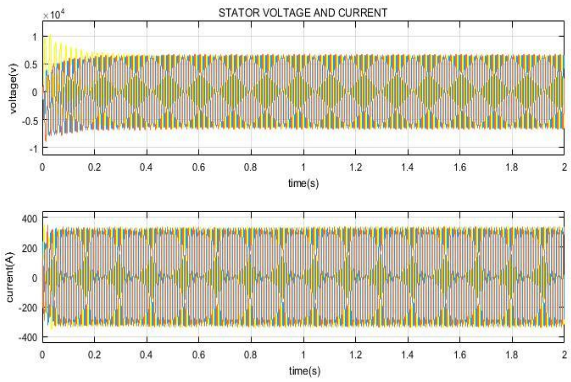
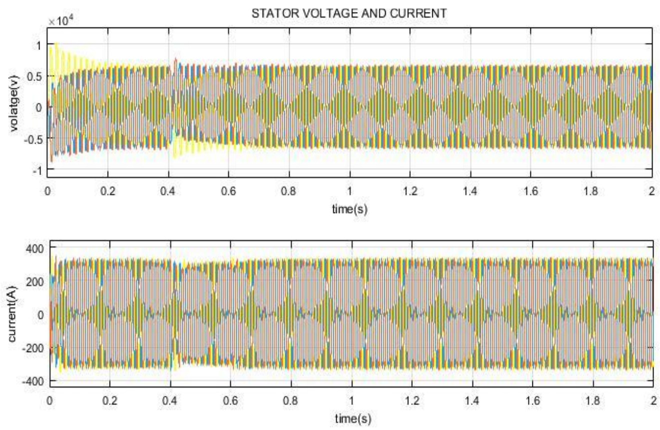


Figure 1.7 Grid voltage and current

Performance of the proposed configuration under three-phase symmetrical LLL-G fault

Stator voltage and current



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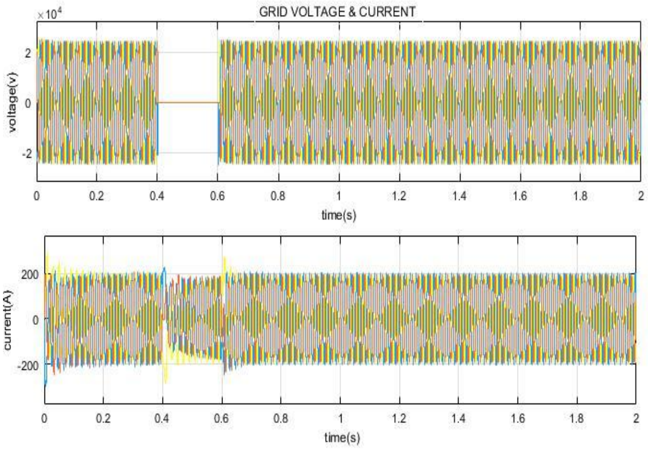

Figure 1.8 Grid voltage and current

Figure 1.7 represents solar voltage and solar current when a symmetrical fault is introduced in the grid side. Figure 1.8 represents grid voltage and grid current when a symmetrical fault is introduced. A severe symmetrical fault is enforced at the upstream grid side when normal power is being generated. Fault is identified by realizing the magnitude of positive sequence voltage, grid current is injected by GIC and the turbine does not show any variation in operating condition as MIC sustains stator voltage even though severe fault. A symmetrical fault occurs at t=0.4 seconds and the fault exists for 0.2 seconds after which grid current from GIC is being injected. The required reactive current is injected by GIC to meet the grid codes. Thus in the proposed configuration turbines seamlessly ride through the fault.

VIII. CONCLUSION

The conventional fundamental transformer is replaced with SST. Direct interface with SST is made by which active power could be injected. The requirement of GSC is eliminated as the active power from RSC or vice versa is adjusted by MIC. The power generated by wind energy and solar energy is integrated and it is interfaced to load using Solid State Transformer. The SST achieves voltage conversion through thearray of power electronics devices while offering multiple advantages like, smaller in size, enhanced power quality. The reactive current is fed by GIC during occurrence of symmetrical fault hence fault ride through occurs as per recent grid code requirement. When there is failure of wind energy generating system the solar energy is being used, the wind energy is connected to the proposed system using DC bus. When the wind energy generation is deficient, the GIC is also used to give reactive power to the system.

FUTURE ENHANCEMENT

In future a similar power electronic device could be developed with reduced number of stages of conversion and this could decrease the volume and size of the device further. The efficiency can be increased as the loss that occurs during conversion process is reduced.

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