DVR BASED POWER QUALITY IMPROVEMENT USING DFIG, FUEL CELL AND SUPER CAPACITOR

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Abstract—The Doubly Fed Induction Generator (DFIG) based Dynamic Voltage Regulator (DVR) is used for the consumer protection from the grid voltage fluctuation like long duration voltage variation and short duration voltage variation. This paper analyses the operational principle of DFIG base DVR. It is designed by PI control technique and the decision making switch is used to compensate long duration and short duration voltage variations. Super capacitor and fuel cell (hybrid system) is used to compensate the fault during short duration voltage variations. DFIG is used to compensate the long duration voltage variations. The DFIG based DVR is established using MATLAB/Simulink.

Keywords—DVR, DFIG, Long and Short-Duration Voltage Variations, Pulse-width modulated (PWM), Decision making switch; Grid, Bidirectional Isolated DC–DC Converter, SESD.

1. INTRODUCTION

Power system experiences better change in electric power generation, transmission and distribution. In long interconnection network the electrical load growth and high power transfer leads to complex and less secure of the power system operation. In order to make it more flexible and controllable manner the power system engineers are facing challenges to operate the system. This plays an important role for the beneficial utilities between supply and demand. The increased utilization facilitates the flexibility, reliability and efficiency of the renewable sources for short duration voltage variation and long duration voltage variation. Voltage quality and frequency quality are the two categories in the power system issues. The issues of the voltage quality are voltage sag, voltage swell, under voltage and over voltage. In case of frequency quality the issues are transient and harmonics. Voltage sag is the most occurred issue because of the usage of voltage sensitive devices.

Based on the application super capacitor is classified as short term response and long term response energy storage devices. Short term responses are flywheel, super capacitors. Long term responses are hydrogen fuel cell, batteries, Redox flow. The DVR which is series connected is most cost effective for long and short duration voltage compensation.

The DFIG based DVR is evaluated for dynamic response using MATLAB simulation.

The direct energy storage and the indirect energy storage are the two energy storage device which is shown in fig.1. The categories of energy storage devices are

(i) Less than 10MW is small category

(ii) 10MW < energy < 100MW are medium categories

The medium category includes large scale batteries, lead acid, NAS and Redox

(iii) ≥ 100MW are large categories

The large category includes compresses air storage (CAS), pumped storage.

The small category includes flywheel, batteries, ultra capacitor and capacitors.
2. DFIG WITH DVR

The basic structure of DVR based DFIG is shown in fig.3. It consists of DFIG, decision making switch, voltage source inverter, transformer, PWM, PI controller, grid, hybrid system (super capacitor with fuel cell).

The practical applications of simulated voltage variation are indicated by a discrete pulse width modulation scheme. The main aim of the control scheme is to maintain constant voltage magnitude even at system disturbances. The various phase faults are created at load voltage due to long and short duration voltages. Load voltage is passed through sequence analyzer after converting it to the per unit quantity.

The error signal is fed to PI controller after the magnitude is compared with reference signal.

The magnitude is then compared with reference voltage through which error signal is fed to PI controller. This voltage is then fed to triggering circuit. PWM control technique is applied for inverter switching so as to produce a three phase 50 Hz sinusoidal voltage at the load terminals. The range of Chopping frequency is a few Kilo Hertz. The PI controller is controls the IGBT to maintain 1 per unit voltage at the load terminals that is considered as base voltage is equal to 1 p.u. voltage. The DVR control system exerts a voltage angle control as follows:

The PI controller processes the error signal and generates the required angle \( \delta \) that drives the error signal to zero, e.g.; the load rms volt is brought back to the reference volt. Here we need to make an assumption of balanced network and operating conditions. The modulating angle \( \delta \) is applied to the pulse width modulation generators in phase A, here the phase angles B and C are shifted by 240° or -120° and 120° respectively.

\[
V_A = \sin (\omega t + \delta) \quad (1)
\]

\[
V_B = \sin (\omega t + \delta - 2\pi/3) \quad (2)
\]

\[
V_C = \sin (\omega t + \delta + 2\pi/3) \quad (3)
\]

An advantage of a proportional plus integral controller is that integral term causes the steady-state error to be zero for a step input. The input for PI controller is an actuating signal which is the difference between the \( V_{ref} \) and \( V_{in} \). The controller block output is of the form of an angle \( \delta \), in the three phase voltages which introduce additional phase-lag/lead. The error detector output is

\[
V_{ref} - V_{in} = (4)
\]

\( V_{ref} \) - equal to 1 p.u. voltage

\( V_{in} \) - voltage in p.u. at the load terminals.

The controller output when compare at PWM signal generator results in the desired firing sequence.

3. HYBRID BIDIRECTIONAL DC–DC CONVERTER TOPOLOGY

The fuel cells (FCs) and super capacitors (SCs) as a hybrid system it is an environmentally renewable energy system. It has been applied in many fields like hybrid electric vehicle, UPS so on.

The controller output when compared at PWM signal generator results in the desired firing sequence.
On the primary side of T1 a BHB structure is located which is associated with the switches S1 and S2 operate at a duty cycle of 50%. The auxiliary energy source is with SC bank that has variable low voltage dc bus across dividing capacitors C1 and C2. Between the SC bank a high voltage bidirectional operation is realized. The switches S3 and S4 reduce the current stress and ac RMS value which is controlled by the duty cycle. When VFC or VSC are input over a wide range.

To realize galvanic isolation and boost a low input voltage to HVDC bus, the transformer T1 and T2 with independent primary winding as well as series connected secondary windings are employed. In series with the primary winding T2 a blocking cap Cb is in series to avoid transformer saturation which is caused due to asynchronous operation in full bridge circuit.

To increase voltage conversion ratio the voltage doubled circuit on secondary side is utilized. Between the LV side and HV side a power delivering interface element is used which is utilized by the inductor L2 on the secondary side. The proposed converter according to power flow direction there are three modes as boost mode, SC power mode and SC recharge mode.

The power is delivered from FCs and SCs in boost mode. The required load power is provided by SCs which is in SC power mode. The direction is reversed by charging the SCs, this transfers energy from HV side and LV side. Under SC recharge mode the converter is operated.

4. DFIG WITH GRID CONNECTION DESIGN

DFIG based WPGS (Wind turbine Power Generation System) with voltage source converter at the rating of 25% to 30% of the generator rating used in the high power applications. DFIG are used for varying speed of machines shaft in a synchronous speed. The DFIG in different parts of control strategies are used in the wind energy conversion system.

The most popular wind turbine is DFIG that includes an induction generator along with slip ring, a back to back voltage source converter and a DC link capacitor with common. The two main parts of power electronics are grid side converter (GSC) and the receiver side converter (RSC). To the grid three phase stator winding are connected by slip ring and brushes through a power converter. The full controllability over the system is with back to back power converter.

Fig. 6. Fuel cell simulation model.

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5. DECISION MAKING SWITCH

The simulation model for decision making switch is shown in Fig.9. During fault condition the energy source is applied by the decision making switch. By using fuel cell
and super capacitor (hybrid) system the short duration voltage variation is compensated. Based on availability long duration voltage variation is compensated. The availability is based on DFIG and grid.

6. DFIG BASED DVR TEST SYSTEM

Based on DFIG, the single line diagram of test system is 13kV, 50Hz generating system. A 3 winding transformer is connected in star/delta/delta of 13/115kV is fed through two transmission lines. The two transformer connected in delta/star, 115/11kV and 11/500kW which is fed through the transmission line. Voltage compensation at 0.44ohm fault resistance at 0.08sec of fixed time duration. The working of DVR is verified for the symmetrical three phase to ground fault. The DVR is performed by DFIG.

The MATLAB/Simulink diagram for long and short voltage variation of DFIG is shown in fig.10. At a point with fault resistance of 0.04ohm for the time duration of 0.08 and 0.3sec. The first simulation was carried without DFIG based DVR and three phase to ground fault is applied, this results in voltage sag. DFIG based DVR is introduced to voltage sag due to three phase to ground fault which is carried out at second scenario.

Fully charged condition for battery backup is shown in fig.11. 30V output of hybrid system for fuel cell was modeled and output is shown in fig.14. The output for the hybrid bidirectional dc–dc converter is shown in fig.15. The voltage level for fault condition in transmission line is shown in fig.16. The fig.17 illustrates the controller pulse output for decision making switch. Short term voltage variation of fault clearing by using DFIG and DVR and clearing long term voltage variation, the response of battery backup support, super capacitor and fuel cell (hybrid system) for short voltage variation is illustrated by the fig.19.

Fault clearing of DFIG based DVR only supports for the clearance of long term voltage variation and the short term voltage response for super capacitor and fuel cell is shown in fig.20. With grid support fault clearing of DFIG based DVR for clearing long term voltage variation and short term voltage response with super capacitor and fuel cell hybrid system is shown in fig.21.

Fig. 10. Phase-phase voltage without any fault.

Fig. 11. Backup battery voltage output.

Fig. 12. PV output voltage.

Fig. 13. PV output with converter output voltage.

Fig. 14. Fuel cell output voltage.

Fig. 15. Hybrid bidirectional dc–dc converter topology output.
CONCLUSION

A Doubly Fed Induction Generator (DFIG) based DVR is incorporated as a new design, which is mitigates long and short duration voltage variation which enhances distribution system of power quality. The simulation result proves that DFIG can be a useful alternative source for the DVR.

REFERENCE

