Voltage Compensation and Fault Current Limiting Using Dynamic Voltage Restorer

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***Abstract*—This paper proposes a new fault current limiting dynamic voltage restorer concept. The new system has a crowbar bidirectional Thyristor switch across the output terminals of a conventional back-to-back DVR. In the event of a load short, the DVR controller will deactivate the faulty phase of the DVR and activate its crowbar Thyristor to insert the DVR filter reactor into the grid to limit the fault current. A fault condition is detected by sensing the load current and its rate of change. The DVR will operate with different strategies of protection under different fault conditions.**

Keywords— Dynamic voltage restorer, Fault current, voltage compensation, shunt transformer, Crowbar bidirectional circuit

I. INTRODUCTION

Voltage fluctuations and short circuit faults. With wide use of nonlinear loads, the grid suffers from voltage fluctuation, voltage unbalance, and other power quality problems. At the same time, many power loads become more sensitive to these disturbances [1], [2]. The rapid proliferation of renewable power generation sources in the grid has aggravated these power quality problems [3]–[6]. Furthermore, short-circuit faults remain one of the most common faults in the grid and cause great concerns for grid security and stability.

A solid-state fault current limiter can be used to limits fault currents in the grid [7]–[12]. , the solid-state FCL inserts a high series impedance in the power loop and thus effectively limits the fault current if when a short circuit fault occurs. In during normal operation of the grid the FCL operate in a non-load mode, resulting in compromised equipment utilization Efficiency and energy conversion efficiency. Then, a dynamic voltage restorer (DVR) can be used to compensate the grid voltage fluctuations. For manypower systems, it would be tremendously advantage to provide both voltage compensation and fault current.
Limiting functions by a single power electronic equipment. , the strategy control of a conventional DVR is expanded to additional fault current interruption features. , this approach requires a three-fold increase in power rating of the DVR, leading to a sharp increase in system cost.

II.TOPOLOGY AND OPERATION

A DVR is a power electronics switch device that contains of SCR, a capacitance bank as energy memory device and injection transformers. it will be seen that DVR is connected in between the distribution system and therefore the load. The DVR is that by suggests that of associate injecting transformer a bearing voltage is generated by a forced commuted device that is asynchronous to the bus voltage. A regulated Direct Current voltage supply is provided by a DC capacitance bank that acts associate energy memory device.

Below normal in operation conditions no voltage sag present, DVR provides very minimum magnitude of voltage to atone for the free fall of transformer and device losses. however, if have a voltage sag in the distribution system, DVR can generate a controlled voltage of high magnitude and desired point that ensures that load voltage is uninterrupted and is maintained. During this case the capacitor are discharged to stay the load offer constant.

Note that the DVR capable of generating or riveting reactive power however the reactive power injection of the device should be provided by associate external energy supply or energy storage system. The interval of DVR is incredibly short and is limited by the ability physics devices and therefore the voltage sag detection time.

In this paper, a new concept of fault current limiting dynamic voltage restorer is proposed. The new topology can operate in two operational modes:

1) Voltage compensation mode;
2) Fault current limiting mode.

The topology of the composed of three single-phase bridges. Each s phase topology mainly comprises of a parallel transformer, a back-to-back power converter, a series transformer, and a crowbar bidirectional Thyristor. The input module inverter of the converter is connected to the grid through a parallel transformer (e.g., T1) with Lz to eliminate the maximum frequency ripples, and rectifies the power from the grid to the dc capacitor. The output module inverter converts the power from the dc capacitor to voltage compensation, and is connected to the grid through a series transformer (e.g., T4) and a LC output filter. The input rectifier module and output inverter module are connected through the dc link capacitor Cd. The bidirectionalThyristor crowbar in every phase is across the output terminals of the output module inverter to provide circuit fault current limiting function. us, udc, uc, uDVR, and ul represent the voltage supply, the dc link voltage, the output voltage of the DVR, the output voltage of FCL-DVR on the primary side of the series transformer, and the voltage of point of common coupling (PCC), respectively. Is represents the supply current, and il is the load current. Zs and Zl are the equivalent impedances of the grid and the transmission line, respectively.

The significant difference between the new FCL-DVR and an ordinary DVR is the expansion of three crowbar bidirectional thyristors. The crowbar bidirectional Thyristor

for each stage will be deactivated or activated relying upon the task conditions. At the point when the lattice is under typical task, the crowbar bidirectional thyristors is deactivated and the FCL-DVR works in the voltage compensation mode to repay voltage fluctuation when a short circuit fault occurs, the crowbar bidirectional thyristors is activated to insert the output inductor into the main current path through the series transformer. , the insulated gate bipolar transistors (IGBTs) of the pulse width modulation (PWM) inverter will be killed to totally deactivate the inverter. The FCL-DVR in this manner works in the fault current limiting mode. The short circuit fault current can be restricted by L through the crowbar bidirectional Thyristor. The maximum fault current can likewise be controlled by altering the conduction-point of the Thyristor. In this manner, both voltage fluctuation and fault current limiting can be furnished by the FCL-DVR with a similar power rating of a regular DVR.
At the point when a short circuit or a voltage sag happens, the change of supply voltage will impact the strength of dc connect voltage. In the event that the three shunt transformers are delta-associated on the high-voltage side, the voltage change on the low-voltage side is littler than the connection mode. Delta-connection can also suppress the 3rd harmonics caused by the fluctuation of dc link voltage.

MODES OF OPERATION

Voltage Compensation Mode: When FCL-DVR works in the voltage compensation mode, the crowbar bidirectional Thyristor is deactivated. The FCL-DVR works as a conventional DVR, so it can be identical to a voltage controlled voltage source, as appeared in at the point when voltage variance or unbalance happens, FCL-DVR can be controlled as a compensation voltage u1, which is in arrangement with the supply voltage. So the load voltage can be kept up, and the power quality can be made strides. The input module of back to back converter is utilized to supply the dc connect voltage.

Fault Current Limiting Mode: When the FCL-DVR works in the Fault current limiting mode, the single-stage equal circuit of FCL-DVR is appeared. At the point when a short out blame happens, the faulty phase of the inverter is deactivated, and the crowbar bidirectional thyristors is activated. Under this condition, the reactor L enters into the framework on the secondary side of the arrangement transformer, so the fault current can be restricted by the reactor. As the supply voltage relatively managed by the arrangement transformer, the information rectifier module of the back to back converter can work

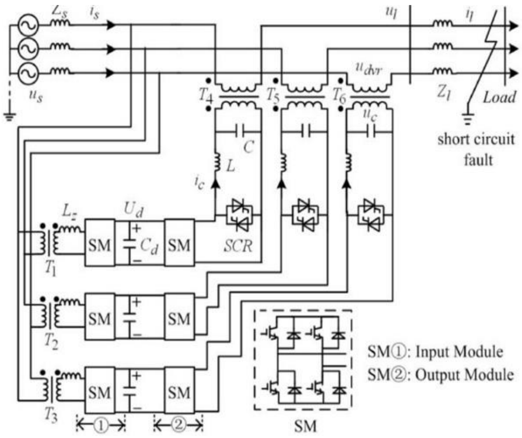


Fig2.

As shown in, in order to eliminate high frequency ripples the L and C are usually resonant at a high frequency, then $n^2\omega_0 L = 1/\omega_0 C$. Where$\omega_0$is the fundamental frequency, and n is usually greater than 10. Compared with the equivalentimpedance of C, the equivalent impedance of L is very small. So the impact of filter capacitance can be neglected. The equivalent impedance of the secondary side of the series transformer is given by

$$Z_{eq2}=\omega_0 L * \frac{\pi}{2\pi - 2\alpha + \sin 2\alpha} \quad (1)$$

Whereα is the trigger delay angle of the crowbar thyristors.

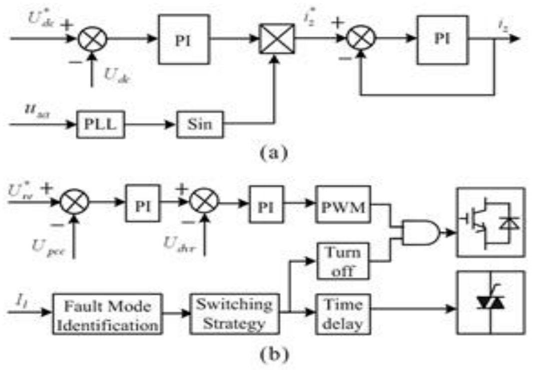
III. CONTROL DESIGN

The control block diagram of FCL-DVR is shown in Fig. 4. Shows the control block diagram of the input rectifier module to maintain the dc link voltage. Fig. 4(b) shows the control block diagram of the output inverter module and crow-bar bidirectional Thyristor to carry out voltage compensation and fault current limiting functions

As mentioned before, the FCL-DVR can operate in one of the two operation modes according to the grid state. There are two main aspects that influence the performance of the FCL-DVR: the operation mode switching strategy and fault current detection method. When the FCL-DVR is in the voltage compensation mode, it operates as a conversational DVR. Much work was done on the control methods of DVR [8]–[10], [19]. So we mainly focus on the switching strategy and fault current detection method of the fault current limiting operation mode.

As shown in Fig. 4(a), a control method based on instantaneous value of dc link voltage, input current of PWM rectifier, and PCC voltage is adopted in this paper [20]. Using this con-trol method, a fast response, low steady state error of voltage compensation can be obtained. The three-phase topology is composed of three single phase bridges and each phase can be controlled individually, so the unbalance compensation can be carried out easily.
When a short circuit fault happens (e.g., a three-phase to ground fault) the fault current will be 6–10 times that of the normal load current [17]–[19]. Assuming the fault current in

steady state is λ times of the load current. When a short circuit fault occurs, the ratio of change of fault current is $\lambda*\omega$ times larger than that of the normal current [21]. So by sensing the ratio of change of current, short circuit fault can be detected with a fast speed. But it is easily to be influenced by disturbances. To make sure that the fault current can be detected fast and accurately, a fault current detection method by sensing the load current and its rate of change is developed, as shown in Fig. 5. i_{re} is the reference value of fault detection, which is larger than the peak value of load current. t is the sampling period. i_l and $i^F{}_l$ are the differences between the adjacent sampling values of load current and fault current, respectively



Switching Strategy

Case 1: The grid is in ordinary state, and no short circuit fault happens. New DVR works in voltage compensation mode, and the crowbar bidirectional thyristors are deactivated. In this state the compensation voltage of FCL-DVR is zero. It goes about as a go through for the dynamic transmission.

Case 2: PCC voltage changes/imbalances and no fault happen. FCL-DVR works in voltage remuneration mode and the crowbar bidirectional thyristors are deactivated.

Case 3: Transient single-stage to ground fault happens. FCL-DVR works in voltage compensation mode, and the crowbar bidirectional Thyristor are deactivated. FCL-DVR compensates the PCC voltage. The power network resumes to a typical state automatically while the fault vanishes.

Case 4: Permanent single-phase to ground fault occurs. The good phases of FCL-DVR operate in voltage compensation modes and all crowbar bidirectional thyristors are deactivated. The crowbar bidirectional thyristors of the faulted phase become activated and the faulted phase of FCL-DVR operates in the fault current limiting mode. Then it will return to the voltage compensation mode after the fault condition is removed.

Case 5: Transient short-circuit faults (i.e., phase to phase short-circuit fault, two-phase to ground fault and three-phase to ground fault) occur. The healthy phase of FCL-DVR operates in voltage compensations mode; the fault phases are in fault current limiting mode. The voltage compensation command of the fault phase is set to zero, and the inverter of the fault phase is deactivated. The corresponding crow-bar bidirectional thyristors are activated. In this state, the PWM rectifier of the fault phase operates well to maintain the dc voltage, and it prepares for the recovery of FCL-DVR. When the fault disappears, the grid resumes to normal operation status automatically; and the fault phase of FCL-DVR recoveries to voltage compensation mode.

Case 6: Permanent short-circuit faults (occur. Like in Case 5, the healthy phase of FCL-DVR operates in voltage compensation mode; the fault phases are in fault current limiting mode. The fault phase of back-to-back converter is deactivated, and the correspond-ing crowbar bidirectional thyristors are activated. Until the faults are eliminated, the fault phase of DVR networks.

IV. SIMULATION AND RESULT

The supply voltage is set at 10 kV with a 1 MW resistive load. The FCL-DVR is designed to compensate a volt-age fluctuation of 20% of the supply voltage. The maximum fault current is allowed to be six times of the nominal load current. The parameters are summarized

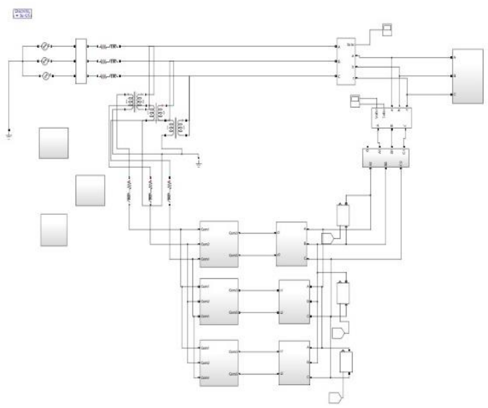


Fig 4.1

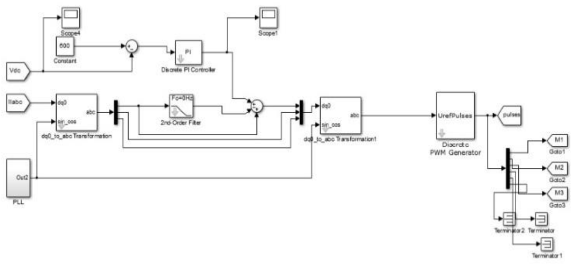


Fig4.2

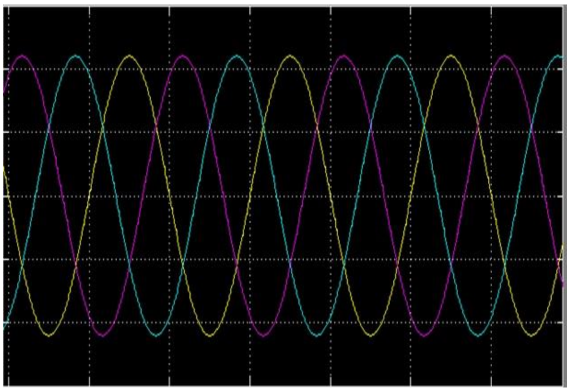


Fig 4.3

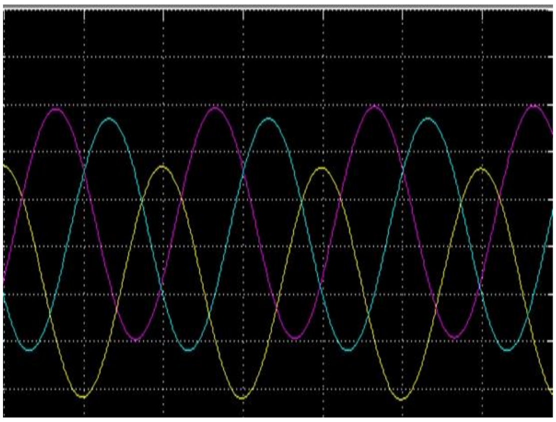


Fig 4.4

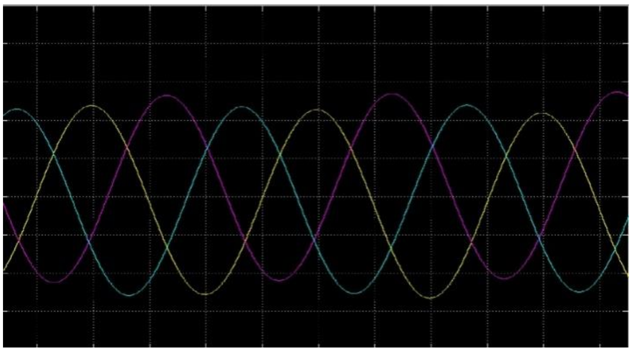


Fig 4.5

In the above represented pictures Fig 4.1 is the whole setup of the simulation .In the Fig 4.2 represent the proportional integral controller of the simulation

In the Fig 4.3 is the normal voltage without any fluctutations.in the next picture 4.4 indicates the voltage with voltage with fluctuation

In the final figure Fig 4.5 indicates FCL DVR can compensates the voltage and fluctuations

V. CONCLUSION

The new method usesa conventional back-to-back DVR with crowbar bidirectional Thyristor switch across the output terminals. In the load short event, the DVR controller will stop function of the faulty phase of the DVR and crowbar thyristorsactivate limit the fault current against DVR filter. The FCL-DVR will operate with different types of strategies under different conditions of fault

1) The crowbar bidirectional thyristors between the output sides of the inverter, the new FCL-DVR is done voltage compensation and limiting fault current.

2) The FCL-DVR can be used to help against various types of short faults with some non-fault phases. The FCL-DVR and power rating and conventional DVR. Power rating are same

3) Mode should be delta connection, the shunt transformers minimizes the of dc link voltage fluctuations and suppresses the third harmonics.

4) The new control method can easily detect faults

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