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Flux Charge Controller for Fault Current Interruption Using DVR

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***Abstract* — The paper proposes an alternative control strategy for downstream fault current interruption using a dynamic voltage restorer (DVR). In case of downstream fault large fault current will flow through DVR. And if DVR is not effectively limited it may result in voltage sag at PCC, leading the fault condition further worse. So as to control the drift of huge line current, thereby to reimpose the PCC voltage and to defend the DVR elements, a fault controlling concept is suggested for downstream fault and coupled with DVR operation. The proposed controller achieves fault current limitation by magnitude control of its injection voltage. The study results performed in the MATLAB/SIMULINK platform indicates that the discussed scheme could control the fault current value to less than nominal load current value and restores the voltage magnitude at point of connection within less time.**

Keywords—Flux charge controller, DVR , Fault current interruption

I. INTRODUCTION

The increased concern about the quality of power has paved much research attention towards the designing of custom power devices. DVR is series custom power device meant to protect loads. It supplies controlled ac voltages in series with supply voltages, to enhance voltage quality by adjusting the magnitude, shape, and phase angle of voltage [1]. The main components of a DVR are shown in Fig. 1. That includes a series injection transformer Ti, voltage source inverter, harmonic filter, dc-link capacitor CDC, and power storage device.

When a fault occurred within the upstream of transmission system, the function of the DVR is to act against reduction in voltage or sag caused by that fault. This action is achieved by injecting a controlled voltage in series with supply voltage. The series compensator-DVR is available throughout the duration so there will be slightly minimum delay in delivering the voltage backup when required.

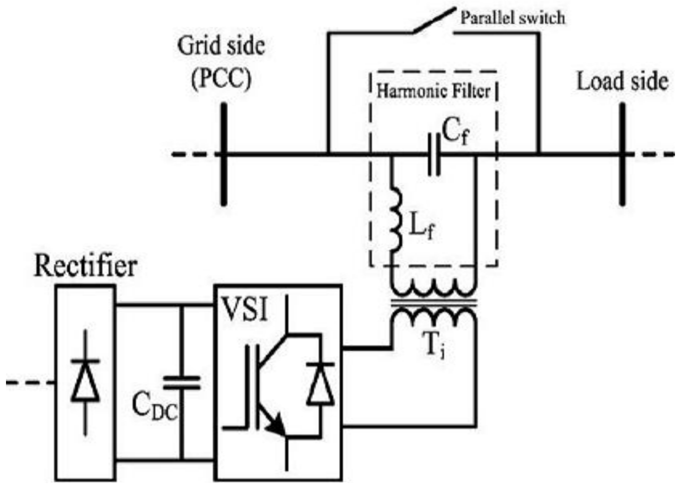

Fig. 1. Schematic diagram of the DVR

Majority of the studies on DVR make sure that it can act suddenly and effectively in case of a fault in upstream. But faults occurs on the downstream side also. Conventionally DVR is bypassed during a downstream fault. This is to avoid potential adverse impacts on the fault and to protect the DVR components against the fault current. Downstream fault occurs on the tie-line linking the DVR and the load. Since the DVR is serially coupled to the faulty line, huge current will be injected through the series transformer and to the converter system. This may damage the compensator if there is no proper measure to control the fault current.

To divert the fault at downstream, whole can depend on circuit breakers (as parallel switch in Fig. 1) connected at upstream of DVR .In all situations existing of fault for large duration may damage sensitive switching devices [4].DVR usually follows a bypass strategy to take care of the sensitive elements from exceeding the its rating due to the large induced currents developed during fault. Sometimes DVR is provided with SCR thyristor shorting switch.

The bypass switch is excellent in defending the DVR, but it cannot interrupt the effect of fault on the shunt loads. So, these strategy could not solve the crisis as whole [2]. Thereby to limit the drift of huge line currents, to reimpose the voltage at PCC and to defend the DVR system elements, a fault current limiting concept (for downstream) based on hysteresis controller is proposed with the DVR operation.

The limiting concept of fault current by the DVR disables the main and the backup protection. This may results in prolonged fault duration [3]. Thereby the DVR is only preferred to control the fault current to zero, interrupt it and pass a trip signal to the upstream protective device or to circuit breaker (CB).

Since fault current interruption (FCI) function requires 100% voltage injection capability ,the power ratings of series injection transformer and the VSC is preferred be about three times those of a conventional DVR with about 30%–40% voltage injection capability. Obviously this may lead to an expensive DVR system[5] [7]. But the economic feasibility of such a DVR system depends on the importance of the sensitive load to be protected by the DVR. The effectiveness of the suggested method is studied via various simulation studies in the MATLAB/SIMULINK environment.

II. PROPOSED CONTROL STRATEGY

The adopted DVR converter is comprised of three independent H-bridge VSCs that are connected to a common dc-link capacitor. These VSCs are series connected to the supply grid, each through a single-phase transformer. The proposed FCI control system consists of three independent and identical controllers one for each single-phase VSC of the DVR.To improve the dynamic response LCL filter is used here.The control diagram for proposed DVR is given in Fig. 2.

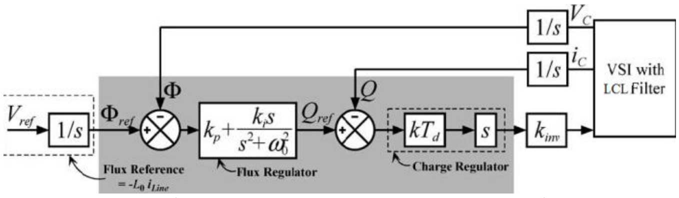

Fig. 2. Schematic of the per phase DVR controller with LCL filter in FCI mode

To interrupt the fault current, flux-charge model has been proposed .Here DVR behaves like a pure virtual inductance which will not absorb any real power from the external system and thereby protects the dc-link capacitor and it's source. For flux-model control (see Fig. 2), the feedback variable used, is the inverter terminal flux, which is defined as :

$$\Phi = \int V_C . dt \qquad (1)$$

and its reference is calculated as $\Phi_{ref} = -L_0 . i_{Line}$, where V_C and i_{Line} represent the filter-capacitor voltage and output current of the series inverter . The flux error is then fed to the flux regulator, which is a P+Resonant controller, with a transfer function . To stabilize the system, an inner charge model is therefore considered. In this loop, the filter inductor charge, which is derived by integration of its current, tracks the reference charge output of the flux regulator.

The charge control variable is defined as :

$$Q = \int i_C . dt = C_f . V_C \qquad (2)$$

where i_C and C_f are the current and capacitance of the filter capacitor of series inverter. The calculated charge error is then fed to the charge regulator with the transfer function as shown in Fig.2.

III. PRINCIPLE OF LCL FILTER

The first-harmonic, low order harmonic and high order harmonic current could be got by decomposing the output current of inverter. As shown in Fig. 3, the current ripple is decreased because of inductance L1 that the current flow through. The capacitance is features low resistance to high order harmonic, but the inductance is features high resistance, so the high order harmonic can only flow through capacitance. Then the left current of first-harmonic and low order harmonic flow through inductance L2 into power grid. The bode diagram of L and LCL filters is shown in Fig. 4.

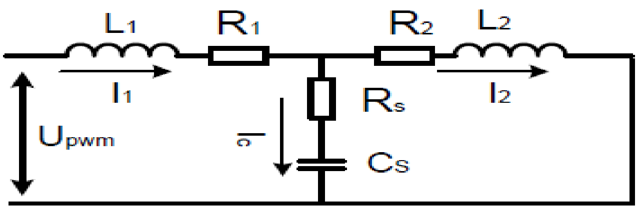

Fig.3. Circuit diagram of LCL filter

As shown in Fig.4, in the range higher than resonance frequency, the attenuation rate of LCL filter is －60dB/dec and the L filter is －20dB/dec. In the high frequency range the LCL filter achieves the better performance than L filter. In the low frequency range the LCL filter achieves the performance as the same as L filter, and the inductance of LCL could be considered L1 plus L2.Therefore, in the high frequency range the LCL filter hasthe good attenuation characteristics. To achieve the same filtering effect of the case, the LCL filter core is smaller and lower cost.

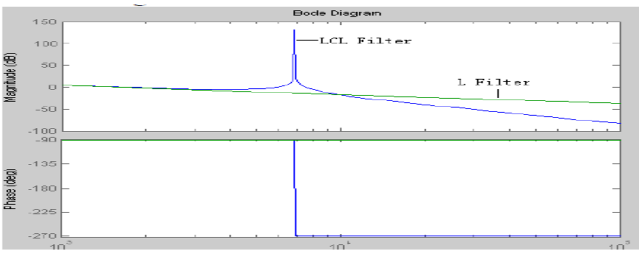

Fig. 4. Bode diagram of LCL filter

III. STUDY RESULTS

For the evaluation of the suggested DVR control system under different fault scenarios, model of a distribution system used in MATLAB/SIMULINK simulation environment is shown in Fig. 5.

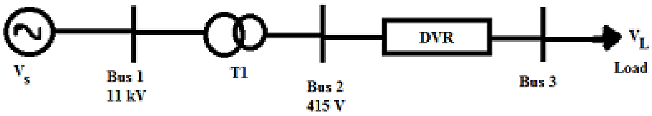

Fig. 5. One-line diagram of the distribution system used for study.

A 500-kVA DVR system is placed on 415V feeder, to protect a 300 kVA, 0.90 lagging power factor load. Here, base voltage for per-unit values is the nominal phase voltage itself. Voltage and current waveforms of A, B, C phases are respectively plotted by solid, dashes, and dotted lines. The various fault simulation studies made on distribution system modeled above is described below.

A. Three-Phase Downstream Fault

Bus 3 of the system shown in Fig. 5 is subjected to a three-phase short circuit with a negligible fault resistance at 0.15 sec . Prior to the fault initiation, the DVR is inactive or in standby mode. During the fault, if the DVR is bypassed, as shown in Fig. 6 the voltage at Bus3 drops about 0.3 p.u. and the fault current increases to about 20 times the rated load current .

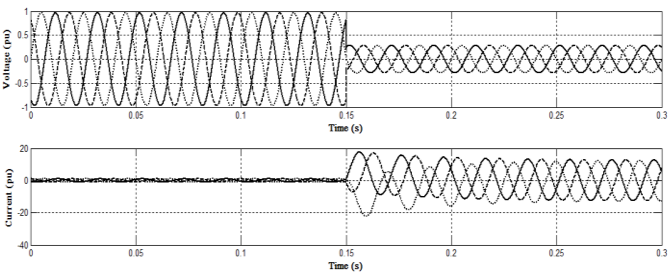

Fig. 6. (a) Voltages at Bus 3. (b) Fault currents, during downstream three phase fault when the DVR is inactive .

Using the proposed controller for DVR the same system shown in Fig. 5 is simulated. Fig. 7(a)–(b), shows the restored three-phase supply-side voltages, and the three-phase load-side voltages respectively. Load voltage is reduced to zero to interrupt the fault currents. The source voltage is restored and Fig. 7(c) illustrates that the proposed FCI method limits and interrupts the maximum three-phase fault current effectively within short interval of time.

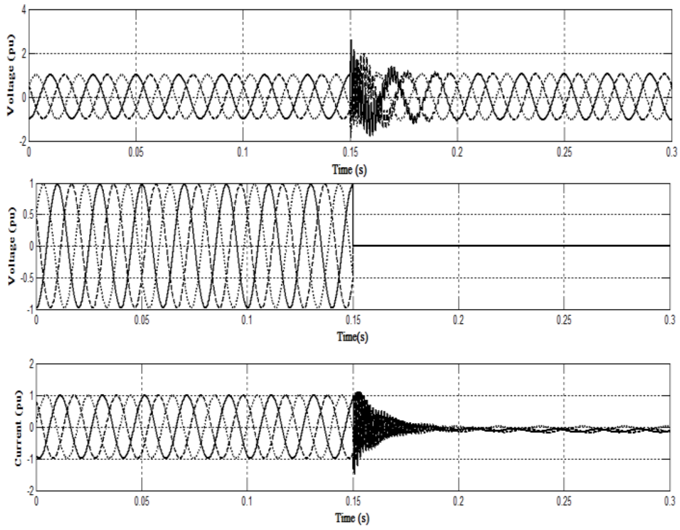

Fig. 7. (a) Source voltages. (b) Load voltages. (c) Line currents during the three-phase downstream fault

B. Line-to-line Downstream Faults

The system of Fig. 5 is subjected to a phase-A to phase-B fault with a fault resistance of 0.001.Fault is initiated at 0.15 sec. When the DVR is inactive or bypassed during the fault, as shown in Fig. 8 the PCC voltage drops to 0.6 p.u and also the fault current increases to about 13 times the rated load current. That is high fault current flow through the system.

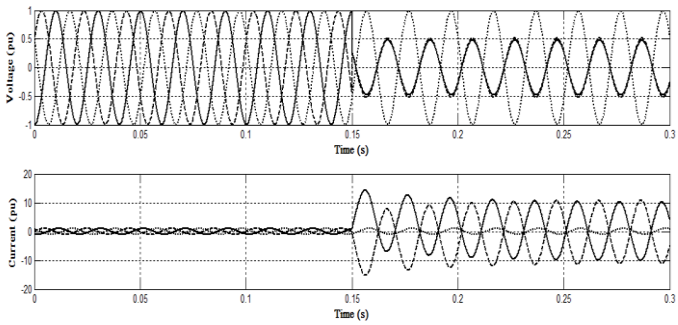

Fig. 8. (a) Voltages at Bus 3(b) Fault currents, during downstream phase-to phase fault when the DVR is inactive

Fig. 9 (a)–(b), respectively, shows the restored supply-side voltages, and the load-side voltages. Supply side voltage is restored and load side voltage is reduced to zero to interrupt the fault currents and the line currents. FCI control successfully interrupts the fault current and restores the source voltage of the faulty phases within less time. It also shows that only the two faulty phases of the DVR is affected, and the healthy phase is not interrupted.

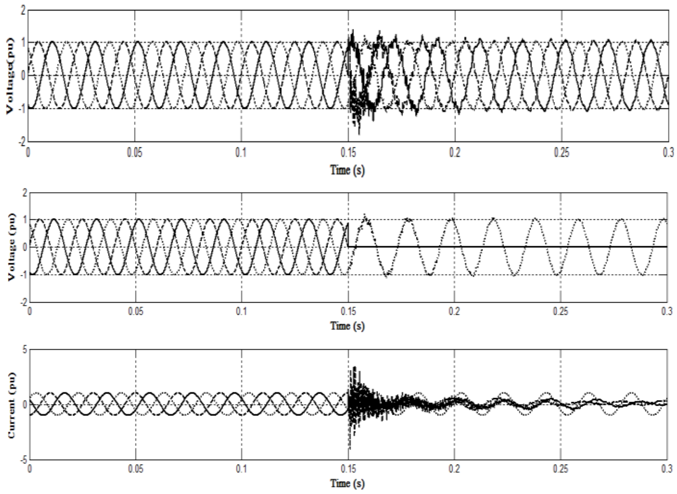

Fig. 9. (a) Source voltages. (b) Load voltages. (c) Line currents during the line-line downstream fault

C. Line-to-Ground Downstream Fault

Phase-C of the system shown in Fig. 5 is subjected to a fault with a negligible resistance of 0.001and the fault is initiated at 0.15 s. If the DVR is inactive, as the result shown in Fig.10, the voltage at PCC considerably drops to about 0.2 pu and the fault current increases 16 times rated current for the faulty phase C.

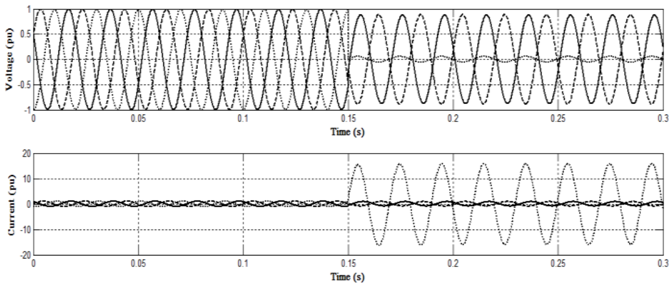

Fig. 10. (a) Voltages at Bus 3 (b) Fault currents, during the downstream single phase- to-ground fault when the DVR is inactive.

Fig. 11 (a)–(c), respectively, shows the restored supply-side voltage for the faulty phase, the load-side voltage and the interrupted fault current. Load side voltage for faulty phase are reduced to zero to interrupt the fault currents and the line currents while the healthy phase remains the same in magnitude. FCI control successfully interrupts the faulty current and restores the voltage of the faulty phases within less time. It also shows that only the faulty phase ,phase C of the DVR is affected, and the healthy phases are not interrupted.

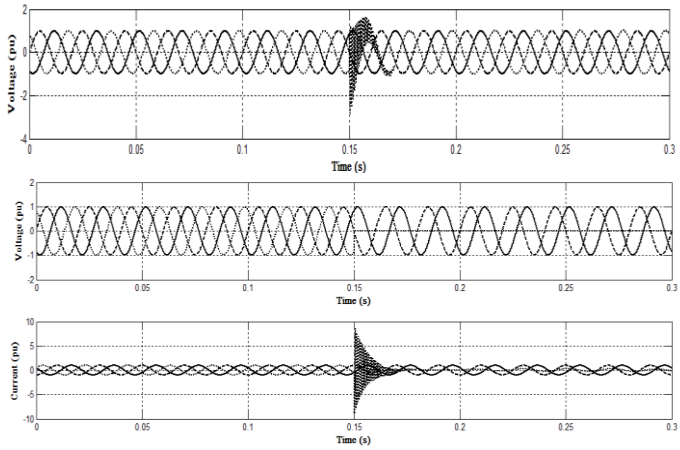

Fig. 11. (a) Source voltages. (b) Load voltages. (c) Line currents. during the single-phase-to-ground downstream fault.

IV. CONCLUSION

The paper proposes an alternative control mechanism with lcl filter which enables the DVR to interrupt downstream fault currents in a radial distribution feeder system. Using MATLAB/ SIMULINK environment the performance of the proposed controller under different fault scenarios are investigated. The effective study points that the proposed controller detects and effectively interrupts the various downstream fault currents within less time duration, specifically less than two cycles.

REFERENCES

[1] N. G. Hingorani, "Introducing custom power," *IEEE Spectrum.*, volume. 32, no. 6, pp. 41–48, June. 1995.

[2] S.S. Choi, T. X. Wang and D.M. Vilathgamuwa, "A series compensator with fault current limiting function," *IEEE Transactions on Power Delivery* ,volume 20, no. 3, pp. 2248–2256, July 2005.

[3] D. M. Vilathgamuwa, P. C. Loh, and Y.Li, "Protection of microgrids during utility voltage sags," *IEEE Transactions on Industrial Electronics* , vol. 53, no. 5, pp. 1427–1436, October 2006.

[4] Y. W. Li, D.M. Vilathgamuwa, P. C. Loh, and F. Blaabjerg, "A dualfunctional medium voltage level DVR to limit downstream fault currents," *IEEE Transactions on Power.Electronics.*, vol. 22, no. 4, pp. 1330–1340, July 2007.

[5] F. Badrkhani Ajaei, S.Afsharnia, A. Kahrobaeian, and S.Farhangi, "A fast and effective control scheme for the dynamic voltage restorer," *IEEE Transactions on Power Delivery*, vol. 26, no. 4, pp. 23982406, October 2011.

[6] Singh Mukhtiar, KhadkikarVinod, Chandra Ambrish, Varma Rajiv K. "Grid Interconnection of renewable energy sources at the distribution level with power quality improvement features". *IEEE Transactions on Power Delivery* 2011;26(1):307–15

[7] Firouz BadrkhaniAjaei, ShahrokhFarhangi, and Reza Iravani, ''Fault Current Interruption bythe Dynamic Voltage Restorer'' *IEEE Transactions on Power Delivery*, vol. 28, no. 2, April 2013