EMTDC 시뮬레이션을 이용한 DVR 시스템 적용에 관한 연구

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A Study on the Application of the DVR System using EMTDC Simulation

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ABSTRACT

Recently, the interest on power quality has been hot issue because the equipments cause voltage disturbance and become more sensitive to the voltage disturbance. The DVR(Dynamic Voltage Restorer) is one of the Custom Power Device that can compensate the voltage. DVR operates as a series connected compensator whose output voltage can be controlled system voltage. And the magnitude of compensation voltage is limited by the characteristics of system and load. Compensation capability of DVR was simulated by EMTDC under several condition. This paper analyzed effect of DVR's compensation at power quality test center which has SSFG(Sag, swell, and Flicker Generator, CPDs(SSTS, DVR, DSTATCOM), and loads.

1. INTRODUCTION

Recently a great deal of interest has been concentrated on the power quality. Various researches are performed to develop a new system for power quality improvement. The actual field research using Power Quality Device has been studied chiefly in America and Japan. By using electronic power device such as FACTS, American have developed custom power devices and their process. Especially, they has constructed Premium Power Park(PPP) with EPRI, AEP, SIEMENS. In the case of Japan, FRIENDS has been accomplished the research for high quality and reliability for customers in the distribution system. The test tools of the power quality which can be applied to the actual system in the de-regulation of Korea have strongly been required. Our researches for power quality were focused on the theoretical studies at the academy and institutes. The developed size is so small that it is not possible to be applied in the real system. We need the actual test equipments and operational skill to be applied to our electric power system. KEPCO has constructed the Power Quality Test Center that has several quality equipments with SSTS(Solid State Transfer Switch), DVR(Dynamic Voltage Restorer),D-STATCOM(Distribution Static Compensator) with LS Industrial Company and Chung Buk National University. The performance of installed compensator was verified and analyzed in detail through simulation with EMTDC for the performance effect of DVR in the middle of the above equipments.

2. Power Quality Test Center

The Power Quality Test Center is sized in 45m×57m and consist of MVP, LVP, DSTATCOM, DVR, SSTS, Diesel Generator, SSFG, Harmonic Filter, Load(Resister and Reactor). And the above equipments are arranged with the high and low voltage separately.

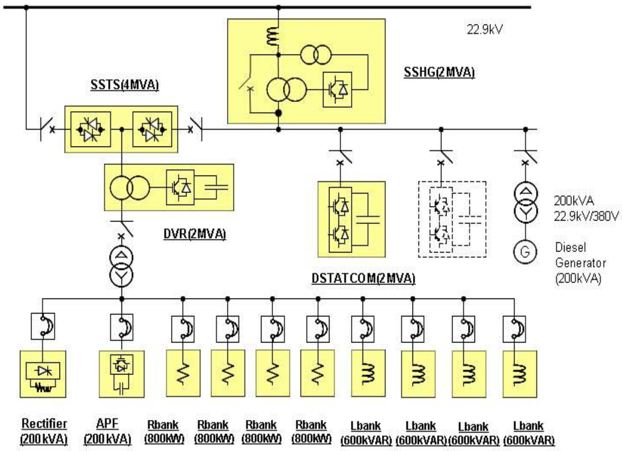


Fig. 1 Single Line Diagram of Power Quality Test Center

The schematic layout for Power Quality Test Center has shown on Fig. 1 and Composition of power quality test center has shown on Fig. 2

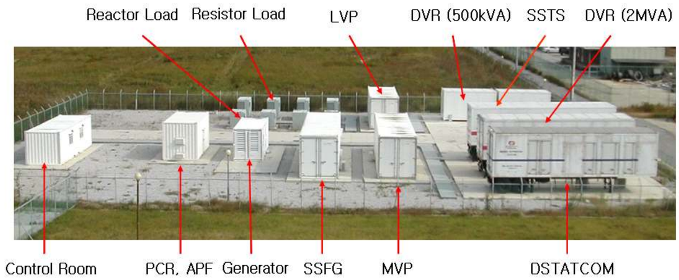


Fig. 2 Composition of Power Quality Test Center

Fig. 3 2MVA DVR

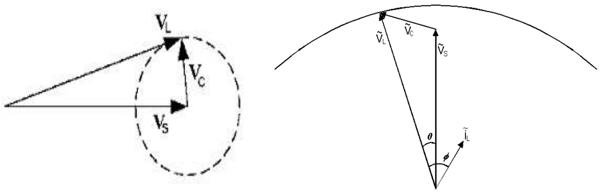
DVR in Power Quality Test Center as shown in Fig. 3 is DC/AC switching power-converter composed of air-cooled voltage source converter. Basically, DVR is able to restore the supply to original magnitude and shape by injecting the vector difference between desired voltage and actual across the load.

Table 1 DVR specification

Items	contents
Rated Power	2MVA
Primary Voltage	22.9kV
Frequency	60Hz
Rated Power	2MVA
3 Phase auxiliary voltage	220V
Power Factor	0.8 Lag
Compensation time	160 ms(10 Cycles)
Charging time	3 minute under

3. Operational Principle

Fig. 4(a) is DVR vector diagram, which shows phasor relationship between the injected voltage and the line voltage. The DVR regulates the magnitude and the phase angle of compensating voltage V_C . The load voltage V_L can be comprised of the source voltage V_S and the injecting voltage V_C with vector relationship.



(a) (b)

Fig. 4(a) Phasor diagram

(b) Equivalent circuit and vector diagram

Detail vector relationship can be derived using the vector diagram shown in Fig. 4(b). An arbitrary value is assigned to the source voltage V_S, and the power factor ϕ is assumed to be lag and constant. The objective of DVR is to maintain magnitude of the load voltage V_L as a constant value. The vector V_L is located on the circumference with a radius of V_L, in which the source voltage V_S makes an angle of a. Therefore, the issue setting a proper injection voltage V_C to a given source voltage V_S is how to determine magnitude of the load voltage and phase angle Θ.

The required active power for the inverter to inject the voltage in series with the line can be expressed as the following equation.

$$P_C = i_L \cdot [v_L \cos(\phi) - v_S \cos(\phi - \theta)]$$

From this equation, output power of the system can be expressed as a sinusoidal function with respect to the phase angle. The minimum value of PC occurs at ϕ = Θ, and the polarity is determined by the ratio of V_S to V_L.

4. EMTDC Simulation

PSCAD/EMTDC simulation is carried out to analyze DVR characteristic. Fig. 6 shows simulation model of DVR which is connected between the source and the load.

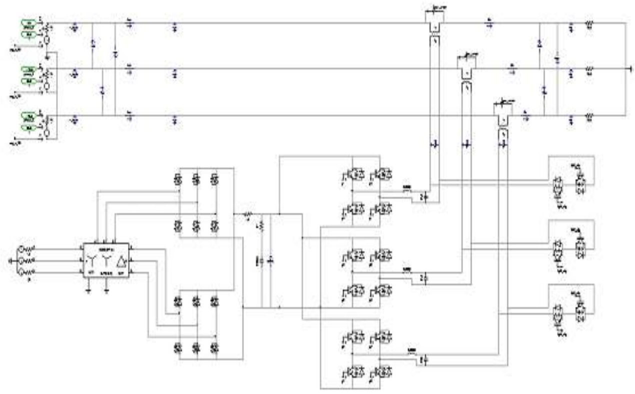


Fig. 6 DVR simulation model

Fig. 7 shows control block diagram to compensate for voltage. DVR controller is composed of normal voltage detect part and Inverter control part. Normal voltage detect part calculates instant voltage(Vsα, Vsβ) of source voltage Vs. PLL(Phase-Locked Loop) circuit decide on basic frequency(ω1) for AC voltage and designed for running on unbalance condition. And injection voltage is calculated by difference between normal voltage and abnormal voltage.

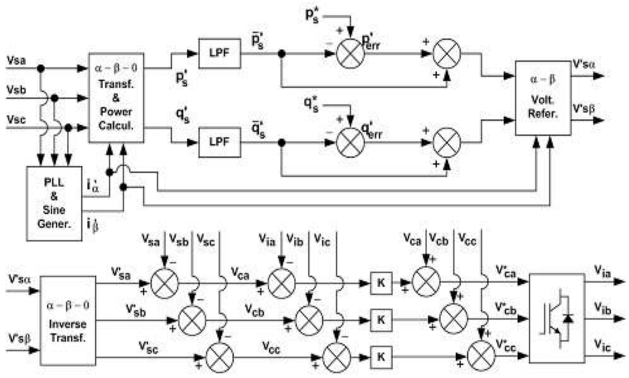


Fig. 7 DVR controller

In order to analyze the operational characteristics of DVR, EMTDC was performed. Two cases for voltage sag and swell are simulated separately.

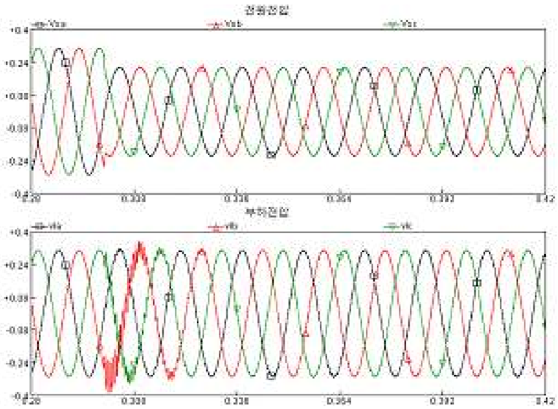


Fig. 8 DVR compensation at 30% sag (EMTDC simulation)

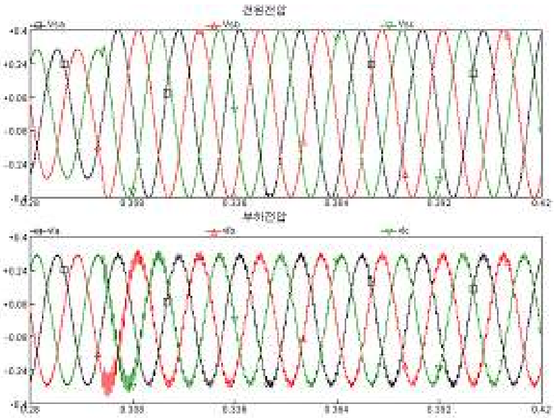


Fig. 9 DVR compensation at 30% swell (EMTDC simulation)

Fig. 8, Fig. 9 shows the characteristics of DVR with sag and swell event. DVR compensates 30% sag well for the 30% sag of SSFG(Sag Swell Flicker Generator) as shown in Fig. 8. and compensates 30% swell of SSFG as shown in Fig. 9.

5. Field Test Results

2MVA DVR was tested to analyze compensation effectiveness as Fig. 10 Fig. 11 The faulted voltage was generated using SSFG.

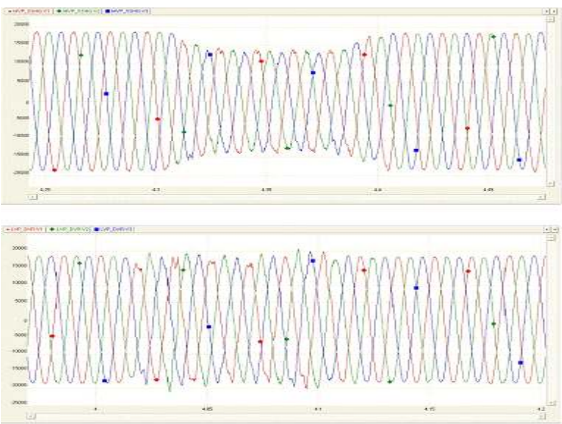


Fig. 10 DVR compensation at 30% sag (Field test)

Fig. 10 shows the source voltage and load voltage respectively. The source voltage is assumed to drop by 30%. Fig. 10 shows the compensated load voltage, which indicates that the sag is properly compensated.

Fig. 11 shows the source voltage and load voltage respectively. The source voltage is assumed to rises by 30%. Fig. 11 shows the compensated load voltage, which indicates that the swell is properly compensated.

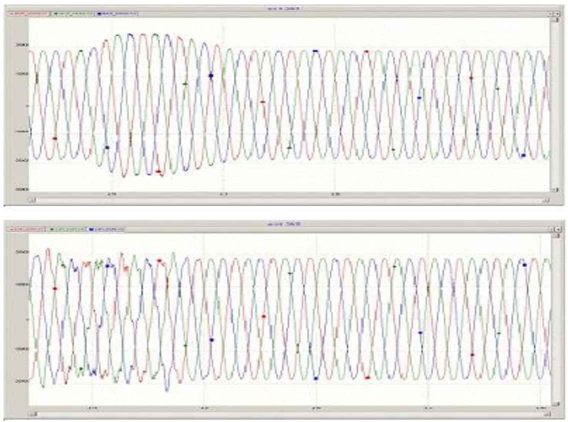


Fig. 11 DVR compensation at 30% swell (Field test)

6. Conclusion

This paper described operation characteristics of DVR, which can continuously compensate the voltage sag and swell for the critical load.

A simulation model with EMTDC was developed to analyze performance of the controller and the whole system. 2MVA DVR was tested for confirming the simulation results. This comparison would help to analyze the effectiveness of DVR and calculation of optimal capacity of PQ devices in Power Quality Test Center.

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