Study on the Feeder Selection method for 10kV Regional Compensation Type Dynamic Voltage Restorer

Abstract: This paper proposes the designing of regional compensation type Dynamic Voltage Restorer(DVR), and the topology of main circuit, the detection algorithm for voltage sag, the calculation method of reference voltage and pulse modulation method. Based on the different load types of the target substation and the sensitivity to voltage sags, the selection principle of the location of compensation line for regional compensation DVR is proposed, and the realization of substation feeder selection method is illustrated by taking a substation as an example. The compensation effect of the DVR under different fault types are simulated, and the validity and rationality of the designing are verified.

Key words: Regional compensation; Dynamic Voltage Restorer; Feeders selection; Pulse modulation; Voltage sag

0 Introduction

With the continuous development of modern industrial technology and the extensive application of computer technology, more and more production processes such as semiconductor manufacturing, paper-making, computer integration adopt microprocessor chip based devices that are sensitive to power quality, even half cycle interruption or dips on the power supply would affect the operation of sensitive equipments, thus causes enormous losses[1,2]. Dynamic Voltage Restorer(DVR) is a device connected in series with the power source and the sensitive load. When the supply voltage is normal, DVR operates bypassed in hot standby state, and when the system voltage dips occurs, it will act quickly to compensate the voltage dips, thus can protect sensitive loads from the effects of voltage sags[3,4].

Currently researched and applied DVRs are almost of the low voltage level, and can compensate voltage drop for one or several the most sensitive devices of users load[5,6]. With the power supply voltage levels, the capacity and concentration rate of sensitive loads continue to increase, this point-to-point compensation form will be increasingly uneconomical. DVR developed to achieve regional voltage drop compensation will have important application value.

Power distribution network includes many types of loads, such as industrial, manufacturing, commercial, residential, transportation, and telecommunications industries, etc. According to different requirements for supply reliability and the loss or affected degree of power interruption in the aspect of politics and economy, it divides into three categories, i.e. class I, II and III load[7,8]. However, on the point of sensitivity to voltage dips, the loads classification will vary. Taking into account the fact that the compensation capacity of current region-based DVR is limited, load distribution with different sensitivity to voltage drops is different. So the prime need is to determine the type of DVR regional protected area, select the line of work, after determine the area to be protected, then related hardware circuit design control strategies and protection work of DVR can be design.

The research and application of the regional type DVR at home and abroad is rare and there are no studies on the feeder selection of regional type DVR. This paper presents the working principle and the system wiring of regional type

DVR. Then the feeder selection criteria and methods the regional type DVR are proposed based on the capacity and nature of the substation 10kV feeder and voltage sage monitoring statistics results. A 110kV substation is taken as an example to show the realization of the feeder selection method. Simulation results in PSCAD verifies the feasibility and effectiveness of the design of regional type DVR.

1 Wiring diagram and working principle of regional type DVR

1.1 System wiring and main circuit topology

Since DVR based on cascaded multilevel topology has the advantages on system reliability, component selection, control complexity, overall efficiency over the other topologies[9-11], the proposed main circuit topology based on multi-level cascade structure of regional type DVR for 10kV three-phase three-wire system is shown in Fig.1:

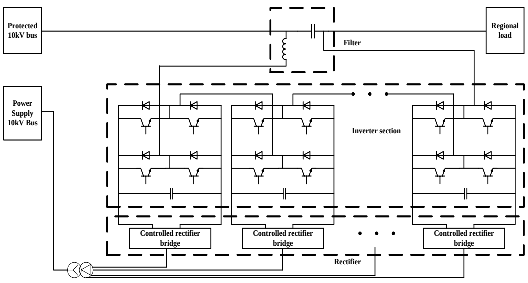

Fig.1 Cascaded Multi-level Topology of DVR

Inverter section uses three single-phase bridge configuration, each phase has 5 cascaded H-bridge; The rectifier uses a controllable rectifier bridge and discharge circuit; Energy storage unit powered from another 10kV bus in the same substation; Output filter and couple circuit uses LC filter.

1.2 Voltage dip detection method

The dq/αβ decomposition methods based on instantaneous reactive power have been widely used in devices such as DVR that are in highly requirement for time delay [12,13]. Fig.2 shows the block diagram of the voltage drop detection algorithm for the regional type DVR.

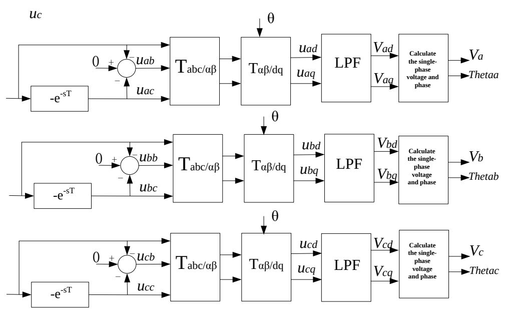

Fig.2 Block diagram of three-phase voltage sag detection algorithm

In Fig.2, e^{-sT} represents time delay, and T=3.333ms； U_a 、 U_b 、 U_c represents the measured phase voltage respectively; U_{ad}、U_{bd}、U_{cd}、 U_{aq}、 U_{bq} and U_{dq} represents the dq components of the three-phase voltage respectively; V_a、V_b、V_c represents three-phase voltage amplitude, and θ is the phase angle. The magnitudes of the voltage obtained are compared with a preset threshold, and the voltage dip can be determined when the voltage magnitudes drops below the 90% of the nominal voltage.

1.3 Reference voltage calculation

At present, the DVR compensation strategies mainly include: the same phase compensation, complete compensation and minimum power voltage compensation[14].

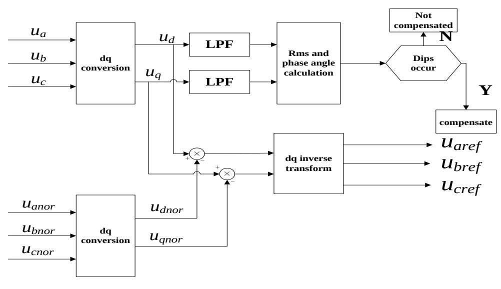

Fig.3 Complete voltage compensation algorithm

The complete voltage compensation algorithm refers to that the amplitude and phase angle of the load-side voltage before and during the voltage drop are exactly the same. This compensation strategy is best for the load, for that the power supply voltage of the load is continuous and without any fluctuations[15]. Since the regional-base DVR proposed in this paper can be energized form another 10kV bus, so the full compensation method can be used. Fig.3 shows the reference voltage calculation process, wherein U_{anor}、U_{bnor} and U_{cnor} are the normal load-side voltages and, U_{aref}, U_{bref} and U_{cref} are the reference voltages of each phase of DVR respectively.

1.4 Pulse width modulation

Multi-level PWM inverter control method can be mainly divided into three categories: the carrier modulation PWM, specific harmonic voltage elimination PWM and space vector PWM. Carrier modulation PWM methods includes: carrier phase shift PWM, carrier layered PWM, switching frequency optimization PWM, step EPWM and segmented carrier wave cascading PWM. For the cascade multi-level inverter, the most widely used are mainly multi-carrier modulation PWM method [16,17].

The regional-base 10kV DVR applies the horizontal phase-shift bipolar carrier PWM control method, the voltage to be compensated is used as modulation signal and a bipolar triangular carrier is the carrier signal and the corresponding control pulse for each IGBT is produced by comparing these two signals. The output voltage of phase A is composed of the output voltages of N basic power unit. For the B phase and C phase, the modulation signal of each of the basic power unit is the same as that of phase A, while the corresponding triangular carrier wave is in sequence phase-shift 2π/3. Fig.4 shows the principle of the horizontal phase-shift bipolar carrier PWM method.

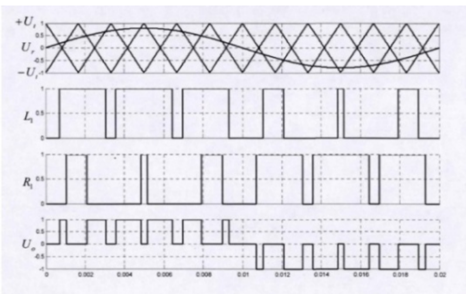

Fig.4 Bipolar Carrier phase-shift PWM

2 Target substation and feeder selections

2.1 Conditions of target substation

The main electrical wiring diagram of a substation is shown in Fig.5:

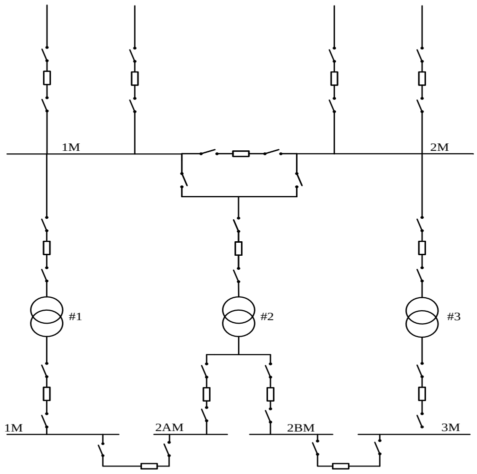

Fig.5 Main connection diagram of a substation

The 10kV bus of the substation is divided into four sections: 1M is powered by the #1 transformer; 2AM and 2BM are powered by #2 transformer and 3M is powered by the #3 transformer. Reactive power compensation capacitor groups are installed on each of the substation 10kV feeder with the total capacity 8016kVar. The total number of the 10kV feeders are 35.

2.2 Feeder selection

According to the characteristics of the regional type DVR and the actual conditions of the target substation, the selection of the installation site of the DVR should satisfy the following principles:

1) The feeders to be protected by DVR should not have class I loads to avoid adverse effects caused by the failure of DVR on such important load;

2) No-load feeders and the feeder with large supply capacity should be excluded. The total capacity of the loads of a feeder should not exceed the capacity of the DVR;

3) Feeders which have loads sensitive to voltage dips, such as semiconductor and industrial parks, should be considered primarily; While the feeders with loads insensitive to

voltage dips, such as residential load, residential areas and utilities can be excluded;

4) Feeders to be protected should be in the same feeder bus to facilitate construction and maintenance;

5) Feeders to be protected should have backup line to avoid the impact on the normal operation of the loads during the failure or of DVR;

6) The total load capacity of the feeder should be less than the 5MW;

7) Voltage sags statistical results Feeder should govern according to nearly three select voltage sag occurs more feeders.

Table.1 shows the voltage sag statistical results of a 110kV substation during the last three years, and Table.2 gives the feeder selection analysis of the 10kV feeder loads according to above principles.

Table 1 Voltage sags statistics of the substation

Bus	Phase	Duration (s)	Voltage drop margin (%)
1M	A	0.039	66.680
1M	C	0.047	40.829
1M	C	0.039	40.284
1M	A	0.055	58.128
1M	B	0.055	63.652
1M	A	0.070	29.019
1M	C	0.039	67.042
1M	B	0.039	53.257
1M	A	0.055	52.233
1M	B	0.047	58.383
1M	C	0.047	41.557
1M	B	0.039	58.849
1M	A	0.031	69.474
1M	B	0.047	52.077

Table 2 Feeder load information of the substation

Num-ber	Load capacity (MVA)	back up	Type of load	Select or not
F01	3.872	Y	Industrial parks	Optional
F03	5.51	Y	Industrial parks	Optional
F05	8.0	Y	Residential district	No/No governance requirement
F07	6.471	N	Residential district	No/No governance requirement
F09	6.91	N	Commercial Building	Optional
F11	1.368	N	No load	No/No load
F13	3.5796	Y	Industrial parks	Optional
F15	4.1496	N	Industrial parks	Optional
F17	0/0	Y	No load	No/No load
F21	5.9508	Y	Commercial Building	Optional
F25	10	Y	Industrial parks	No/Capacity too large
F02	0.5396	Y	Industrial parks	Optional
F04	2.2572	Y	Residential electricity	Optional
F06	1.9418	Y	Industrial parks	Optional
F08	7.1706	Y	Residential electricity	No/No governance requirement
F10	6.346	Y	Residential electricity	No/No governance requirements
F12	8.8806	Y	Industrial parks	No/Capacity too large
F18	3.3668	Y	Industrial parks	Optional
F20	1.0374	Y	Commercial	Optional
F22	5.9926	Y	Industrial parks	Optional
F24	2.9716	Y	Industrial parks	Optional
F26	7.6	Y	Industrial parks	Optional
F41	6.954	Y	/Industrial	Optional

			parks	
F43	10.792	N	Industrial parks	No/Capacity too large
F45	4.2788	Y	Industrial parks	Optional
F47	3.42	Y	Industrial parks	Optional
F49	10.9174	Y	Industrial parks	No/Capacity too large
F51	7.296	Y	Industrial parks	Optional
F53	6.384	Y	Industrial parks	Optional
F55	3.04	Y	Industrial parks	Optional
F57	7.334	Y	Commercial Building	Optional
F59	0	Y	No load	No/No load
F61	6.954	Y	Industrial parks	No/I load
F63	0	Y	No load	No/No load
F65	6.08	Y	Industrial parks	Optional

Based on the feeder selection criteria and the analysis of the feeders of the target substation, the feeder selections scheme of 1M feeder bus are as: F01+F03 feeders, F01+F13 feeders, F01+ F21 feeders, F03+F13 feeders and F13+F21 feeders.

3 DVR compensation effect simulation

According to the results of selected lines, PSCAD simulations model of the regional type DVR has been built. The compensation effects of DVR under different types of faults are analyzed as following:

1) Set a three-phase short circuit fault occurs at 1M bus in 0.5s with the duration of 0.1s, the fault transition resistance is 0.01 ohms. The system and load side voltage of DVR during the voltage dip are shown in Fig.8 and Fig.9 respectively.

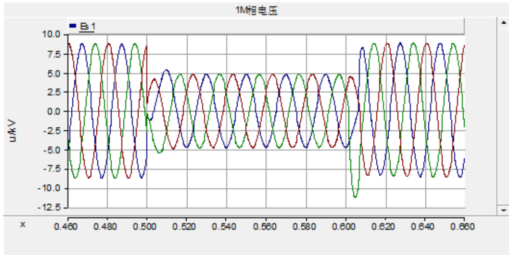

Fig.8 Waveforms of the system voltages

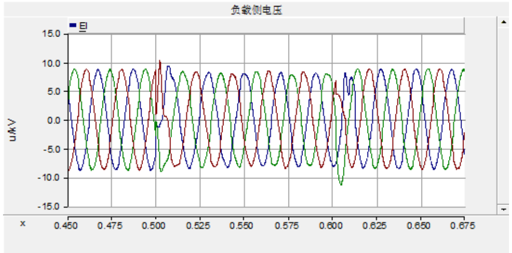

Fig.9 Waveforms of the load voltages

2) Similarly, Set a two-phase short circuit fault at phase A and B in 0.5s-0.6s, the system and load side voltage of DVR during the voltage dip are shown in Fig.10 and Fig.11 respectively.

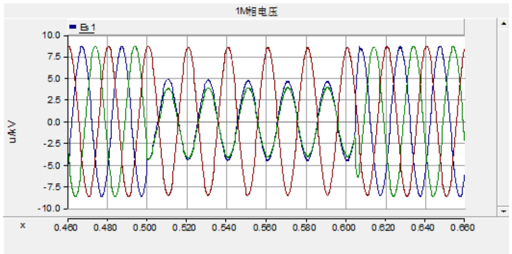

Fig.10 Waveforms of the system voltages

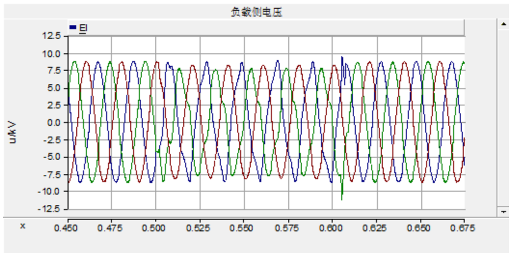

Fig.11 Waveforms of the load voltages

3) Set a two-phase grounded fault at phase A and B, the system and load side voltage of DVR during the voltage dip are shown in Fig.12 and Fig.13 respectively.

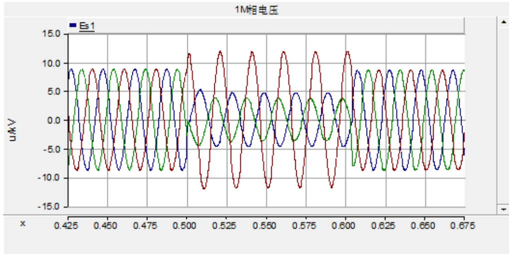

Fig.12 Waveforms of the system voltages

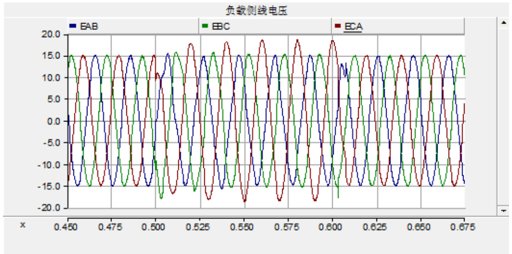

Fig.13 Waveforms of the load voltages

It can be seen from the above simulation results that the installation of the regional type DVR can compensated the voltage dips effectively during different type of faults for the selected feeders, and it verifies the correctness and effectiveness of the design of the DVR system.

4 Conclusions

This paper proposes the application of regional type DVR to compensate voltage dips for several feeders in medium voltage power system. All the types of 10kV feeders loads of a substation are analyzed, and the feeders to be protected are selected according to the feeder selection scheme. Combined with the feeder selection results, the correctness and effectiveness of the design of the DVR proposed in this paper are proved by simulation results.

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