"STUDY OF INRUSH MITIGATION METHOD FOR VOLTAGE SAG"

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ABSTRACT: *Now a day's industries facing the major problem of Voltage sags. Especially for high-tech companies which reside within inside Industry Park, any voltage sag event in the distribution system could affect many manufacturers and inflict significant losses. A number of devices have been suggested to encounter the effects of voltage sags for economic losses and the reliability of power grid. Among these devices, series injection sag compensators are much more. So far there are many researches on series type sag compensators. The voltage-sag compensator, based on a transformer-coupled series-connected voltage-source inverter, is among the most cost-effective solutions to protect sensitive loads. Many voltage-sag compensators adopt open-loop control strategies to increase the response speed for the sag compensation. In this paper going to study the voltage sag and also discuss the how to voltage sag occur in different areas.*

Keywords: Voltage sags, sag compensators, transformer-coupled series

1. INTRODUCTION

Power quality issues have received much attention in recent years, particularly for the high-tech industries which use many sophisticated and sensitive equipment. Survey results suggest that 92% of the interruptions at industrial installations are voltage sag related [7]. One of the most cost-effective solutions to protect against voltage sags is the series voltage-sag compensator based on pulse width-modulated (PWM) voltage source inverters (VSIs) [8][9]. Voltage sags are typically caused by faults in the power grid as well as by switching of heavy loads, starting of large motors and transformer energizing. Traditionally, the quality of supply has been considered in terms of reliability: in other words, the number of cumulative hours of interruptions per year was practically the only important parameter to take into account, whereas the number of short-term outages and voltage sags was not an issue.

2. RELATED WORK

Po-Tai Cheng et. al. [1] proposed a novel technique for mitigating the inrush of the coupling transformer and preserving the output voltage for effective sag compensation. Author gives he detailed explanations of the proposed inrush mitigation technique are presented, and the effectiveness of the proposed scheme is verified by laboratory test results. The inverter-assisted commutation sequence of the bypass thyristors for fast start of the compensator is also presented and verified by test results. With the proposed inrush suppression scheme and the forced commutation scheme of thyristors, the sag compensator can deliver proper compensation voltages within very short time and without the risk of inrush current, which may trigger the over-current protection of the compensator. The inrush suppression scheme eliminates the need for de-rating the coupling transformer, therefore reduces the foot-print and improves the compactness of the compensator system. The proposed AC voltage thrust and the DC voltage thrust associated with the inrush mitigation can drive the flux linkage of the transformer into steady state in approximately one cycle to avoid further magnetics saturation at the starting of the compensator. The compensation voltage may suffer slight reduction due to the inrush mitigation, but the suppression of inrush current is very significant. The offline compensator system using thyristor bypass also improves the operating efficiency, and the thyristor commutation scheme allows fast cut-off of thyristor to ensure the compensation voltage can be delivered very quickly within the time constraint required by SEMI F47 standard.

Pei Chen et. al. [2] proposed a transformer-less series voltage sag topology without energy storage capacitors. This topology is cost-effective by eliminating the large injection transformer and energy storage capacitors that are used in conventional series injection devices. This topology can both be used in three-phase three-line and three-phase four-line systems, and can compensate symmetrical three-phase voltage sags down to 37%, or one or two phase sags down to zero if others at least one phase is rated. Secondly, proposed and illustrates a new compensation control strategy which combines energy optimal control with time optimal control to enlarge the compensating time and draw a minimum amount of energy from the compensator during sags. And then, an asymptotically angle rotation method is proposed to avoid sudden phase jump of the load-side voltage.

Bruno Delfino, et. al. [3] design a device that able to compensate voltage sags, namely a Static Series Compensator (SSC), is thoroughly analyzed, both from the point of view of the choice of the components and their rating and from the stand-point of the control system. The model has been implemented with the aid of the electromagnetic code PSCAD-EMTDC and has been tested in a radial distribution network for the protection of a nonlinear load consisting of a diode rectifier. Its performance has been tested inserting it in a radial distribution network and satisfactory results have been obtained simulating balanced sags (with or without phase jumps) as well as unbalanced ones.

Gregory A et. al. [4] proposed a multilevel series compensator (MSC) to deal with: i) voltage sags/swells, ii) harmonic compensation or iii) reactive power compensation. Such a device can be considered as a dynamic voltage restorer (DVR) or a series active power filter (Series-APF). The MSC can improve the power quality of loads located in stiff systems. The configuration is based on three-phase bridge (TPB) converters connected by means of cascaded single-phase transformers. This arrangement permits to use a single dc-link. A generalization for K-stages in which K transformers are coupled with K-TPB converters, is presented. The topology permits to generate a high number of levels in the voltage waveforms with a low number of power switches. The multilevel waveforms are generated by the converters through a suitable PWM strategy that takes into consideration the transformer turns ratios. Modularity and simple maintenance makes proposed MSC an attractive solution compared to some conventional configurations. Model, PWM strategy and overall control are discussed.

Zenglu Chen et. al. firstly proposed a transformer-less series voltage sag topology without energy storage capacitors. This topology is cost-effective by eliminating the large injection transformer and energy storage capacitors that are used in conventional series injection devices. This topology can both be used in three-phase three-line and three-phase four-line systems, and can compensate symmetrical three-phase voltage sags down to 37%, or one or two phase sags down to zero if other at least one phase is rated. Secondly, this paper proposes and illustrates a new compensation control strategy named as time optimal control which aims to enlarging the compensating time during sags. Using the proposed method, it can be shown that voltage sags can be corrected for much longer time compared to that of existing energy optimal method, and this advantages will be more obvious when the maximum permissible DC link voltage is smaller or in deeper sags. Especially the compensating time during sags by using the proposed control strategy may be several times longer than that of using energy optimal control strategy in the case of lower DC link voltages, deeper sags, and larger load impedance angles.

3. COMPARATIVE ANALYSIS

Sr. No.	Title	Author	Method/ Techniques Used	Advantages	Limitation
1	A Transformer Inrush Mitigation Method for Series Voltage Sag Compensators	Po-Tai Cheng, Wei-Ting Chen, Yu-Hsing Chen, Chih-Hsiang Wang	Inrush mitigation Technique	1] preserving the output voltage for effective sag compensation 2] Improves the compactness of the compensator system. 3] high operating efficiency	Voltage may suffer slight reduction due to the inrush mitigation.
2	A Novel Control Strategy Combined by Both of Energy Optimal and Time Optimal Control for Voltage Sag Compensator	Pei Chen, Zenglu Chen, Yanfang L	• 1] Transformer-less series voltage sag topology without energy storage capacitors. 2] Time optimal control	1] cost-effective 2] Better performance during voltage sags.	Sometimes instantaneous phase jump of the load voltage.
3	An Effective SSC Control Scheme for Voltage Sag Compensation	Bruno Delfino, Federica Fornari, Renato Procopio	synchronous-reference-frame-based control	1] Improve the disturbance rejection capability. 2] Load voltage is less affected by the loading.	----
4	Series Compensator Based	Gregory A, de	Active inrush current	1] Simple and	System cannot

	on Cascaded Transformers Coupled with Three-Phase Bridge Converters	Almeida Carlos, Cursino B. Jacobina	compensator, inverter-based series compensator transformer.	effective control strategy for the reduction of transformer inrush current. 2] Fast response. 3] To improve the power quality on the system.	achieve load voltage compensation.
5	A Novel Transformer-less Series Voltage Sag Compensator without Energy Storage Capacitors and Its New Time Optimal Control Strategy	Zenglu Chen, Pei Zhan, Toshifumi Ise, Yanfang Li, Zhaoan Wang	Static Series Compensator (SSC).	1] Fast response 2] Variation is limited to 1.25%	If permanent fault is occur it breaks the faulted feeder.

4. INRUSH VOLTAGE STUDY

When a voltage is subjected to a transformer at a period when normal steady-state flux would be at a different value from that remaining in the transformer, a current transient happens, known as magnetizing inrush current. The saturation of the magnetic core of a transformer is the key source of an inrush current transient. The saturation of the core is owing to an sudden variation in the system voltage which can be produced by switching transients, synchronization of a generator remains out of phase, outdoor faults and faults renovation. The energization of a transformer produce to the simplest situation of inrush current and the flux in the core may extent a maximum theoretical significance of two to three times the evaluated flux peak.

There is no straight sign that the energization of a transformer can produce an abrupt failure due to high inrush currents. Though, insulation failures in power transformers which are repeatedly energized under no load situation supports the mistrust that inrush current have a dangerous results. The transformer inrush current is the function of several approaches like the terminal voltage switching angle, the remaining flux of the magnetic core, design of the transformer, impedance of the system etc.

Survey results suggest that 92% of interruption at industrial facilities is voltage sag related. The voltage sag compensator, based on a transformer-coupled series-connected voltage source inverter, is among the most cost-effective solution against voltage sags. When voltage sags happen, the transformers, which are often installed in front of critical loads for electrical isolation, are exposed to the disfigured voltages and a dc offset will occur in its flux linkage. When the compensator restores the load voltage, the flux linkage will be driven to the level of magnetic saturation and severe inrush current occurs. The compensator is likely to be interrupted because of its own over current protection, and eventually, the compensation fails, and the critical loads are interrupted by the voltage sag. an inrush current mitigation technique together with a state-feedback controller for the voltage sag compensator. The operation principles of the proposed method are specifically presented, and experiments are provided to validate the proposed approach.

5. VOLTAGE SAG

Voltage sags are the most common power disturbance. At a typical industrial site, it is not unusual to see several sags per year at the service entrance, and far more at equipment terminals. Voltage sags can arrive from the utility; however, in most cases, the majority of sags are generated inside a building. For example, in residential wiring, the most common cause of voltage sags is the starting current drawn by refrigerator and air conditioning motors.

Sags do not generally disturb incandescent or fluorescent lighting. Motors or heaters. However, some electronic equipment lacks sufficient internal energy storage and, therefore, cannot ride through sags in the supply voltage. Equipment may be able to ride through very brief, deep sags, or it may be able to ride through longer but shallower sags.

6. VOLTAGE SAGS OCCUR?

Utility Systems

Voltage sags can occur on Utility systems both at distribution voltages and transmission voltages. Voltage sags which occur at higher voltages will normally spread through a utility system and will be transmitted to lower voltage systems via transformers.

7. CAUSES OF VOLTAGE SAGS

7.1 Utility Systems

7.1.1 Operation of Reclosers and Circuit breakers

If for any reason a sub-station circuit breaker or a recloser is tripped, then the line which it is feeding will be temporarily disconnected. All other feeder lines from the same substation system will see this is connection event as voltage sag which will spread to consumers on these other lines. The depth of the voltage sag at the consumer's site will vary depending on the supply line voltage and the distance from the fault. Typically a higher supply voltage will have larger sag affected zone

7.1.2 Equipment Failure

If electrical equipment fails due to overloading, cable faults etc., protective equipment will operate at the sub-station and voltage sags will be seen on other feeder lines across the utility system.

7.1.3 Bad Weather

Thunderstorms and lightning strikes cause a significant number of voltage sags. If lightning strikes a power line and continues to ground, this creates a line to ground fault. The line to ground fault in turn creates voltage sag and this reduced voltage can be seen over a wide area. Note the lightning strike to ground causes Voltage Sags on all other lines, Circuit breakers and recloses operate more frequently in poor weather conditions High winds can blow tree branches into power lines. As the tree branch strikes the line, a line to ground fault occurs which creates a voltage sag. If the line protection system does not operate immediately, a series of sags will occur if the branch repeatedly touches the power line. Broken branches landing on power lines caused phase to phase and phase to ground faults Snow and Ice build up on power line insulators can cause flash-over, either phase to ground or phase to phase. Similarly snow or ice falling from one line can cause it to rebound and strike another line. These events cause voltage sags to spread through other feeders on the system.

7.1.4 Pollution

Salt spray build up on power line insulators over time in coastal areas, even many miles inland, can cause flash over especially in stormy weather. Dust in arid inland areas can cause similar problems. As circuit protector devices operate, voltage sags appear on other feeders

7.1.5 Animals & Birds

Animals particularly squirrels, racoons and snakes occasionally find their way onto power lines or transformers and can cause a short circuit either phase to phase or phase to ground. Large birds, geese and swans, fly into power lines and cause similar faults. While the creature rarely survives, the protective circuit breaker operates and voltage sag is created on other feeders.

7.1.6 Vehicle Problems

Utility power lines frequently run alongside public roads. Vehicles occasionally collide with utility poles causing lines to touch, protective devices trip and voltage sags occur.

7.1.7 Construction Activity

Even when all power lines are underground, digging foundations for new building construction can result in damage to underground power lines and create voltage sags.

7.2 Industrial Plants

Voltage sags can be caused within an industrial facility or a group of facilities by the starting of large electric motors either individually or in groups. The large current inrush on starting can cause voltage sags in the local or adjacent areas even if the utility line voltage remains at a constant nominal value.

8. REFERENCES

[1] Po-Tai Cheng, Wei-Ting Chen, Yu-Hsing Chen, Chih-Hsiang Wang, "A Transformer Inrush Mitigation Method for Series Voltage Sag Compensators", IEEE, 0-7803-9208-6/05/$20.00 © 2005.

[2] Pei Chen, Zenglu Chen, Yanfang L, "A Novel Control Strategy Combined by Both of Energy Optimal and Time Optimal Control for Voltage Sag Compensator", IEEE, 978-1-4244-3557-9/09/$25.00 © 2009.

[3] Bruno Delfino, Federica Fornari, Renato Procopio, "An Effective SSC Control Scheme for Voltage Sag Compensation", IEEE TRANSACTIONS ON POWER DELIVERY, VOL. 20, NO. 3, JULY 2005.

[4] Gregory A, de Almeida Carlos, Cursino B. Jacobina, "Series Compensator Based on Cascaded Transformers Coupled with Three-Phase Bridge Converters", IEEE, 978-1-4673-7151-3/15/$31.00 ©2015

[5] Zenglu Chen, Pei Zhan, Toshifumi Ise, Yanfang Li, Zhaoan Wang, "A Novel Transformer-less Series Voltage Sag Compensator without Energy Storage Capacitors and Its New Time Optimal Control Strategy", IEEE, 978-1-4244-1668-4/08/$25.00 ©2008.

[6] Po-Tai Cheng, Jhao-Ming Chen, Chia-Lung Ni, "Design of a State-Feedback Controller for Series Voltage-Sag Compensators", IEEE Transactions on Industry Applications, Vol. 45, No. 1, January/February 2009.

[7] D. Sabin, "An assessment of distribution system power quality," in "Statistical Summary Report," Electron. Power Res. Inst., Palo Alto, CA, EPRI Final Rep. TR-106249-V2, May 1996.

[8] D. M. Vilathgamuwa, A. A. D. R. Perera, and S. S. Choi, "Voltage sag compensation with energy optimized dynamic voltage restorer," IEEE Trans. Power Del., vol. 18, no. 3, pp. 928–936, Jul. 2003.

[9] S. S. Choi, B. H. Li, and D. M. Vilathgamuwa, "Dynamic voltage restoration with minimum energy injection," IEEE Trans. Power Syst., vol. 15, no. 1, pp. 51–57, Feb. 2000.