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Evaluation algorithm for system disturbances in fuel cell generation system

Sung-Sik Choi, Gi-Young Kim, Jae-Beom Park, Zakhar V. Semenyuk, Mi-Young Kim, Dae-Seok Rho
Dept. of Electrical Engineering, Korea University of Technology and Education,
1600, Chungjeol-ro, Byeongcheon-myeon, Cheonan, Chungnam, 330-708, South Korea

Abstract- This paper deals with evaluation algorithm for system disturbances in fuel cell systems. Recently, large scale fuel cell generation system (FCGS) with high energy efficiency and low CO2 emission is energetically interconnected with distribution system. However, it is reported that system disturbances such as harmonic, surge, load unbalance and ground system have caused several problems in the large scale FCGS. Therefore, this paper proposes evaluation algorithms to prevent distribution system disturbances. From the simulation results, it is confirmed that the proposed algorithms are useful tools for the stable operation of large scale FCGS.

Keywords- Fuel Cell Generation System, distribution System Disturbances, Unbalance Current, Harmonic, Surge

1. Introduction

Large-scale fuel cell generation system (FCGS) is energetically interconnected with power system because of high energy efficiency and low CO2 emission. However, in the large scale FCGS, it is reported that system disturbances (surge, harmonic, etc.) have caused several problems such as protection device malfunction, control device damage and control signal hunting [1]. Therefore, this paper proposes the evaluation algorithms to prevent system disturbances in FCGS. And also, this paper presents the modeling of large scale FCGS and system disturbances based on the PSCAD/EMTDC and P-SIM software. From the simulation results, it is confirmed that the proposed algorithms are useful methods for the stable operation in large scale FCGS.

2. Modeling of FCGS and system disturbances

In order to analyze the impacts from system disturbances to FCGS, this paper proposes modeling of system disturbances and large scale FCGS based on PSCAD/EMTDC and P-SIM software.

2.1 Modeling of large scale FCGS

This paper performs modeling of FCGS in abnormal operation of tie breaker (TB) trip condition as shown in Fig. 1 [2]. FCGS is composed with 2 fuel cells (each 1.4[MW]), 2 step up transformers (each 0.48/13.8[kV], 2[MVA], △-Y winding connection) and 2 power conditioning system (each 1.4[MVA]). It is connected to distribution system through main transformer (13.8/154 [kV], Y-Y winding connection).

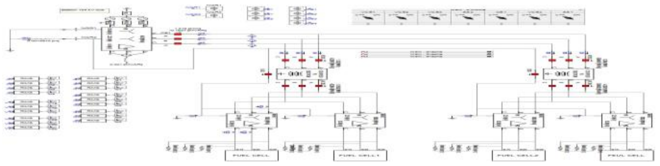

Fig. 1 FCGS modeling

3.2 Modeling of system disturbances

This paper performs modeling of system disturbances such as load unbalance, harmonic and surge for stable operation in FCGS. In order to decrease unbalance current which is occurred at TB trip, the modeling of neutral ground register (NGR) installed at neutral line of step up transformer is presented as shown in Fig.1. And also, the modeling of harmonic filter is presented in Fig. 2, to reduce the 3th, 5th and 7th harmonics.

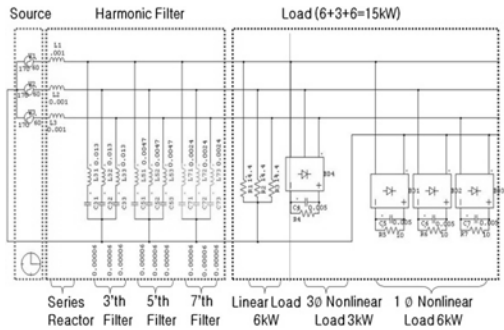

Fig. 2. *Harmonic filter modeling*

In addition, in order to protect transient voltages, the modeling of surge protective device (SPD) is presented in Fig. 3, which is composed of surge arrester (MOSA) and R-L-C filters [3]. This is characterized as high impedance during normal condition and low impedance under surge condition.

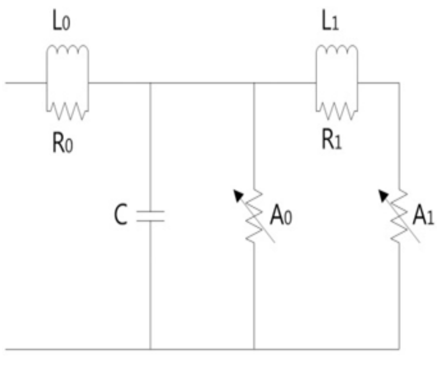

Fig. 3. IEEE SPD Modeling

3. Evaluation algorithm for system disturbances

In order to solve problems such as protection device malfunction and control device damage, this paper presents evaluation algorithms for system disturbances based on electric technical guidelines and grid codes.

3.1 Operation algorithm of protection device

Main goal of NGR operation algorithm shown in Fig. 4 is to estimate optimal NGR capacity to reduce unbalance current. Generally, ground fault current (I_n) of FCGS is calculated by symmetrical component method using % impedance map. Optimal NGR capacity have to be decided under condition that I_n is less than 30% of rated current (I_N) and the effective grounding range of step up transformer is satisfied[4]. The optimal NGR capacity to keep unbalance current within allowable limit can be expressed by Eq. (1).

$$I_0 = \frac{3 \times 100}{Z_1 + Z_2 + Z_0 + 3Z_f} \times I_n \leq I_{set} \tag{1}$$

Where, Z_1, Z_2 and Z_0 are positive-phase, negative-phase and zero-phase impedances, Z_f is NGR capacity, I_n is unbalance current value, I_{set} is OCGR setting value.

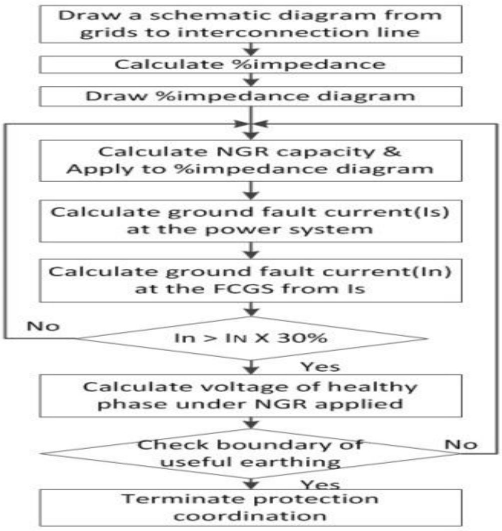

Fig. 4. NGR operation algorithm

3.2 Design of harmonic filter

In order to keep harmonic current less than allowable limit, L-C filter is designed so that each harmonic distortion value measured is less than 3% of basic current as shown in Fig. 5. L and C components of harmonic filter can be calculated by Eq. (2) and Eq. (3).

$$Z_{th} = R + j(wL - \frac{1}{wC})[\Omega[\tag{2}$$

$$L = \frac{1}{4\pi^2 f^2 C}[H] \tag{3}$$

Where, Z_{th} is impedance of harmonic filter and R, L and C are resister, reactor and capacitor of filter.

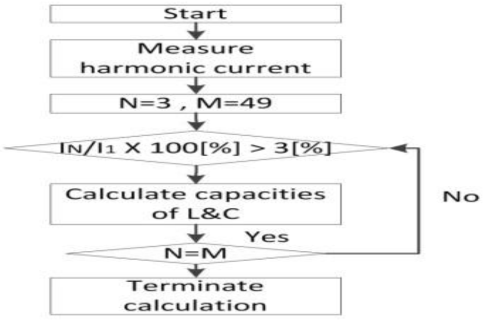

Fig. 5. Design of harmonic filter

3.3 SPD design algorithm

Generally, SPD categories are classified according to energy level base on the electrical technical guidelines. Namely, class 1 SPD and class 3 SPD are covering protection of high level surge and low level surge energies respectively. The optimal level and location of SPD can be determined so that protection and insulation coordination between SPD and other devices are satisfied as shown in Fig. 6 [5].

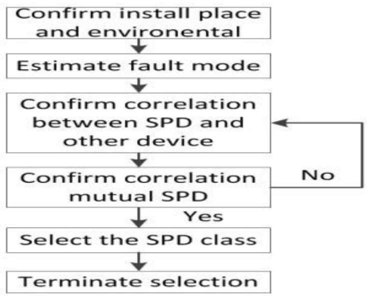

Fig. 6. SPD operation algorithm

4. Simulation results

Regarding evaluation algorithms presented in chapter 3, this paper carried out simulation on the impact from system disturbance to large scale FCGS, using the PSCAD/EMTDC and P-SIM software. Fig. 7 shows the unbalance currents on neutral line when TB is tripped. After locating the optimal NGR of 0.53[H], it is clear that unbalance current reduce to 15[A], which is lower than OCGR setting value 30[A]. Therefore, the presented NGR operation algorithm is valid for preventing malfunction of protection device in FCGS.

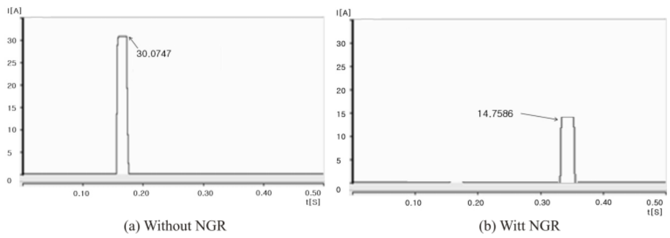

Fig. 7. Neutral line currents

Fig. 8 shows harmonic distortion characteristics before and after L-C harmonic filter designed by the presented algorithm. From the simulation results, it is confirmed that the each harmonic distortions using filter are kept by less than 3% of basic current.

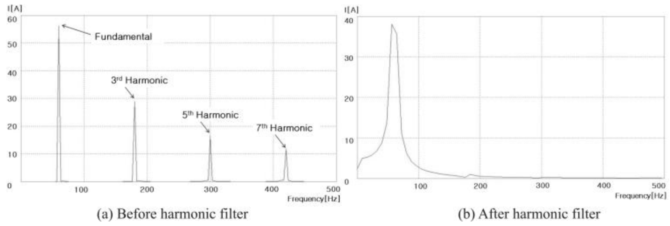

Fig. 8. Harmonic currents

If 2[kV]/1[kA] surge wave is assumed, the residual voltages of class1 SPD are maintained less than 1,200(V) as shown in Fig. 9, which is specified in IEC 61643-12. Therefore, it is confirmed that the presented SPD operation algorithm is valid for surge protection.

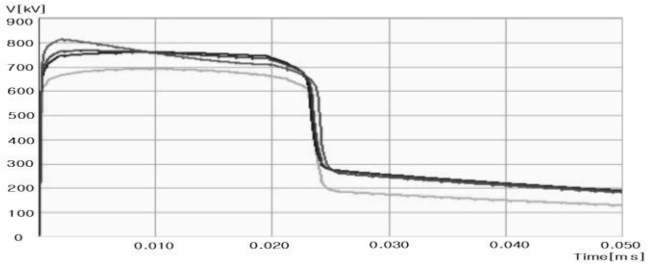

Fig. 9. Residual voltages with SPD

5. Conclusion

This paper proposes the evaluation algorithms to prevent system disturbances such as harmonic, surge, load unbalance and ground system in FCGS. And also, this paper presents the modeling of large scale FCGS and system disturbances based on the PSCAD/EMTDC and P-SIM software. From the simulation results, it is clear that the proposed algorithms are useful tools for the proper operation in large scale FCGS.

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