

Research Article

Ferroresonance Study on the VT in the Karoon 4 Power Plant 400 kV GIS Substation

Seyed Mohammad Hassan Hosseini and Yasertoghaniholari

Department of Electrical Engineering, Islamic Azad University, South Tehran Branch, Tehran, Iran

Abstract: The main subject of the essay is study of ferroresonance in the voltage transformers at 400 kV GIS substation. Ferroresonance has destructive effects such as, undulations of high voltages, warming of transformers, increasing of heat, temperature increasing and damaging voltage transformers, high noise due to evolution due to magnet and bad working of protective instruments. So we have to apply limitations on system parameters to avoid such an undesirable phenomenon like this. In this study ferroresonance phenomenon on VTs of real GIS substation (karon 4 power plant had been studied. With regarding high risk of ferroresonance due to studied substation conditions, damping circuit (FSD, ZD) had been designed with help of EMTP-RV and the results are presented in two conditions of being without damping and by using of damping in the circuit. The results show damping circuit is successful in obviation of these dangerous oscillations.

Keywords: FSD, ferroresonance, Gas Insulated Substation (GIS), Voltage Transformers (VT), ZD

INTRODUCTION

Regarding to the advantages of GIS substations in comparison with AIS (Air Insulated Substation) and purposing that instruments such as current and voltage transformer, bypass disconnect or switch, high voltage conductor, grounding switchgear, breaker and etc., that are kept in boxes under pressure of SF₆ gas and increasing usage of these substations toward the past and regarding to this point that urban and industries areas with increasing load and insufficient area and needing high voltages are regarded, in last year's the use of GIS substation have increased (Tseng and Cheng, 2011).

In this paper we study the Karoon 4 power plant GIS substation that is a 400 kV substation with double bus bar and disconnect or switch, this substation is fed by 4 single phase 100 MW transformers. The outputs of these transformers are connected to the 400 kV network with 4 air lines. Despite the advantages of this gas insulated substations, it has fundamental problems. One of the main ingredients of destruction of the instruments in GIS substations is ferroresonance that influenced the insulation of network at different point. Ferroresonance is one of the rare and destructive phenomena in power network that figured as an on linear resonance that happen between the capacitor of the network and the nonlinear inductance of voltage transformer at the saturation instant. The word of ferroresonance, that arrived to the books and papers from the end of the

second decade of 20th century, use for all the oscillation phenomena in electrical circuits that consist of at least nonlinear self, capacitor, voltage source (generally sinusoidal). The effective elements in causing resonance and ferroresonance in power systems are, harmonic, core saturating, changing inductance of wiring, cutting of 1 or 2 phases of system, unsymmetrical load, inappropriate use of circuit breakers and fuses, using cables with high capacitance. Ferroresonance has other destructive effects such as oscillation of high voltages, intricacy in wave forms of voltage and current, warming of transformers, damaging Voltage Transformers (VT), for example in Karoon 4 power plant 400 kV GIS substation, loud noise due of evolution due to magnet, malfunction protective instruments. Numerous cases of ferroresonance in power system have been reported in years. In last year's the number of ferroresonance because of the intricacy of system and operating modern instrument has increased. Hyundai Reports (2011) and Jacobson (2003) outbreak of ferroresonanc has some signs like permanent over voltage with vast amplitude as phase to phase or phase to ground, permanent over current with vast amplitude, shifting voltage zero point, increasing temperature of voltage transformer, continual increasing of the noise altitude of trans formers and reactors, damaging electrical equipment's such as capacitor banks and CVT because of increasing the thermal effect or breakage of dampers of the protective equipment's. Therefore some

Corresponding Author: Seyed Mohammad Hassan Hosseini, Department of Electrical Engineering, Islamic Azad University, South Tehran Branch, Tehran, Iran

This work is licensed under a Creative Commons Attribution 4.0 International License (URL: <http://creativecommons.org/licenses/by/4.0/>).

limitations should be applied to parameters of systems these (Qing and Yufeng, 2008; Shahabi *et al.*, 2009). All of the studies have been simulated by EMTP-RV software.

PARALLEL CAPACITOR IN HV CIRCUIT BREAKER

Power capacitors have different usage in structure and mechanism of power circuit breaker especially at high voltage levels. Like grading capacitors that have two breaking boxes in series. Voltage usually doesn't distribute equally on breaking boxes. To avoid making stress of high voltage and smoothing voltage on them, capacitors parallel with contacts of circuit breaker that usually have capacity between 900 to 1600 pF for each breaking box are used. Although by the development of technology usage of these capacitors have been reduced but they are used in high voltages yet (Jacobson, 2003; Mohseni *et al.*, 2008). Some defects of these capacitors are increasing the risk of ferroresonance with nearby voltage transformers, increasing the weight, complexity of installation operation and increasing leakage current.

Karoon 4 case study: The purpose of this paper is to study the ferroresonance on Voltage Transformers (VT) in Karoon 4 power plant GIS 400 kv substation as an example of GIS substation with bus bar and long line that have been effected by this phenomenon by

to avoid occurrence of undesirable phenomena like increasing the voltage and damaging isolation and heating, destruction and damaging of VT. These simulations are done by EMTP-RV Software and finally propose the practical method to resist it. There conductive wires of A and C phase of damping reactor have been burnt by the high current at secondary circuit because of the single phase with VT ferroresonance. One of the reasons of this phenomenon is that the VT Company adequately doesn't consider the capacity of the damping reactor to absorb the resonance energy in VT in some cases of GIS switching conditions during first energizing at site. Shoup *et al.* (2011) Special recommendation presented in this study offer to avoiding over heating Beside VT of BUS 1 and 2 and damping reactor until additional FDS (Ferroresonance Detecting and Suppression Device) at site became adjusted. The related Circuit Breaker (CB) for each 400 kV GIS bay should be closed about 5 min after closing of both DS's (disconnecting switches) during energization. Reversely, during power Outage one of both DS's should be opened within 5 min after opening of the circuit breaker (Jacobson, 2003; Abbasi and Seifi, 2009).

On 19 and 24 November in 2010, VT of #1 bus was exposed torero-resonance 2 times during energizing (10 min) and de-energizing (2 min.) by switching of CB and DS of C 03 bay that is shown in Fig. 1.

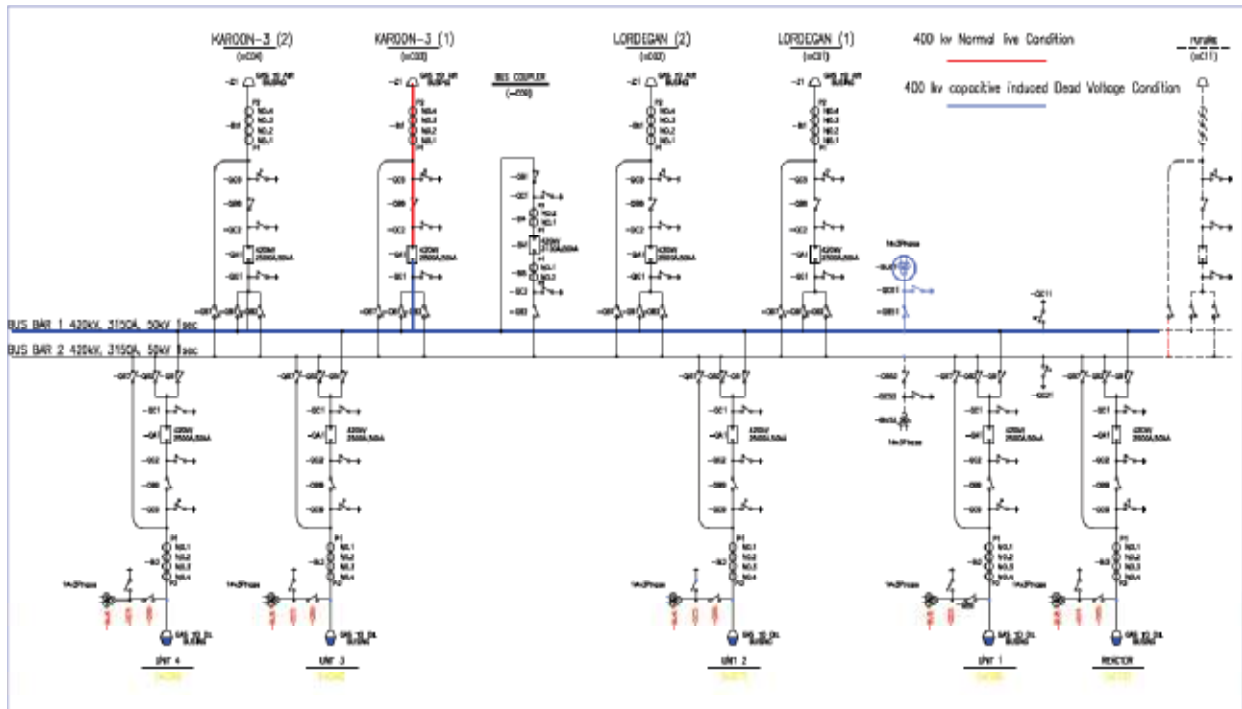


Fig. 1: Karoon4 400kV substation single line diagram state of energizing from first circuit output line of Karon3 and bus 1 and corresponding VT

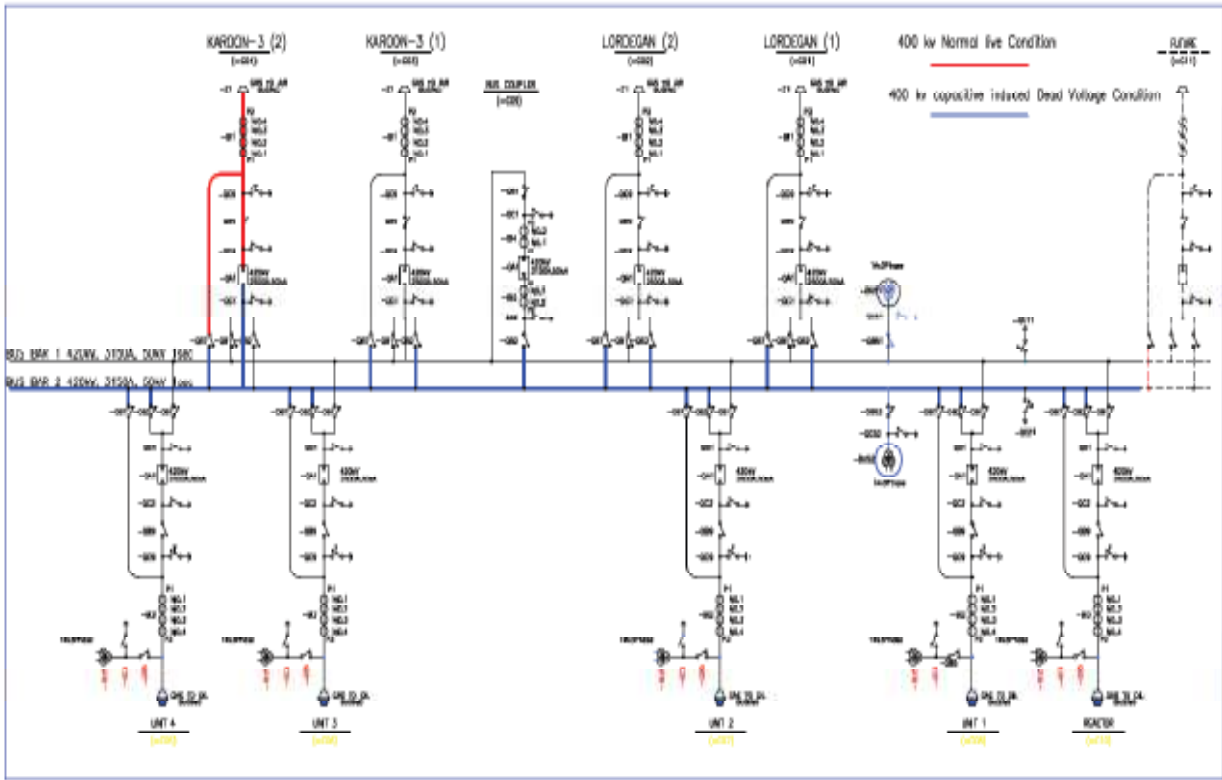


Fig. 2: Karoon4 400kV substation single line diagram state of energizing from second circuit output line of Karoon3 and bus 2 and corresponding VT



Fig. 3: Burnt damping reactor (ZD) of A-phase for #2 Bus VT

On 20 and 21 November in 2010, VT of #2 bus were exposed to ferroresonance 2 times during energizing (5 min) and de-energizing (2 min) by switching of CB and DS of C04 bay through #2 bus bar (Fig. 2 and 3).

FERRORESONANCE DETECTION SUPERVISION DEVISE (FDSD)

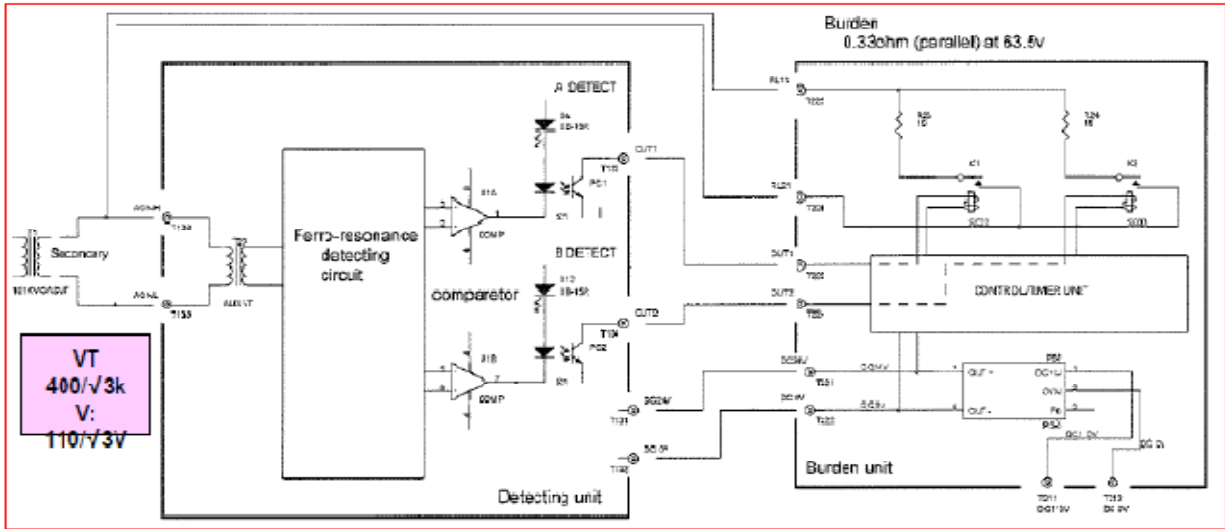
By regarding presented figures of this part such as Fig. 4, a VT with conversion rate of $400/\sqrt{3}$ to $110/\sqrt{3}$ connected to a ferroresonance detector circuit is shown Hyundai Reports (2011). In continue internal circuit of detecting unit is connected to burden with value of 0.33 that is equivalent of parallel branches. And also in

Fig. 5 and 6, appearance of a FDSD and different part of operating lamp A, B, Power Lamp, sensitivity Change, Test Switch, Optional Output Control in three phase and single phase detector unit is shown.

Ferroresonance analysis with FDSD+ZD: The conditions of standard analysis that can be used in done simulation are as below:

- CB Capacitance = 4,000 pF/phase
- Unit Earth Capacitance for GIS = 52.4pF/m
- Internal Earth Capacitance of M.Tr: 13,366 pF/phase
- Internal Earth Capacitance of in Shunt Reactor: 3,382 pf/phase

In above analysis, karoon 4 power plant GIS substation, that is a 400 kV substation with double bus bar with bypass disconnect or switch, is studied and equivalent circuit of GIS substation, that consist of main parameters like, source and resistance series with it and CB that capacitor C1 is parallel with it and as explained at section 3 above GIS circuit breaker had two 2000 pF capacitor parallel with contacts of circuit breaker and equivalent capacitance is 4000 pf. The simulation is done on the basis of these values. Above simulated circuit consist of equivalent capacitor of GIS

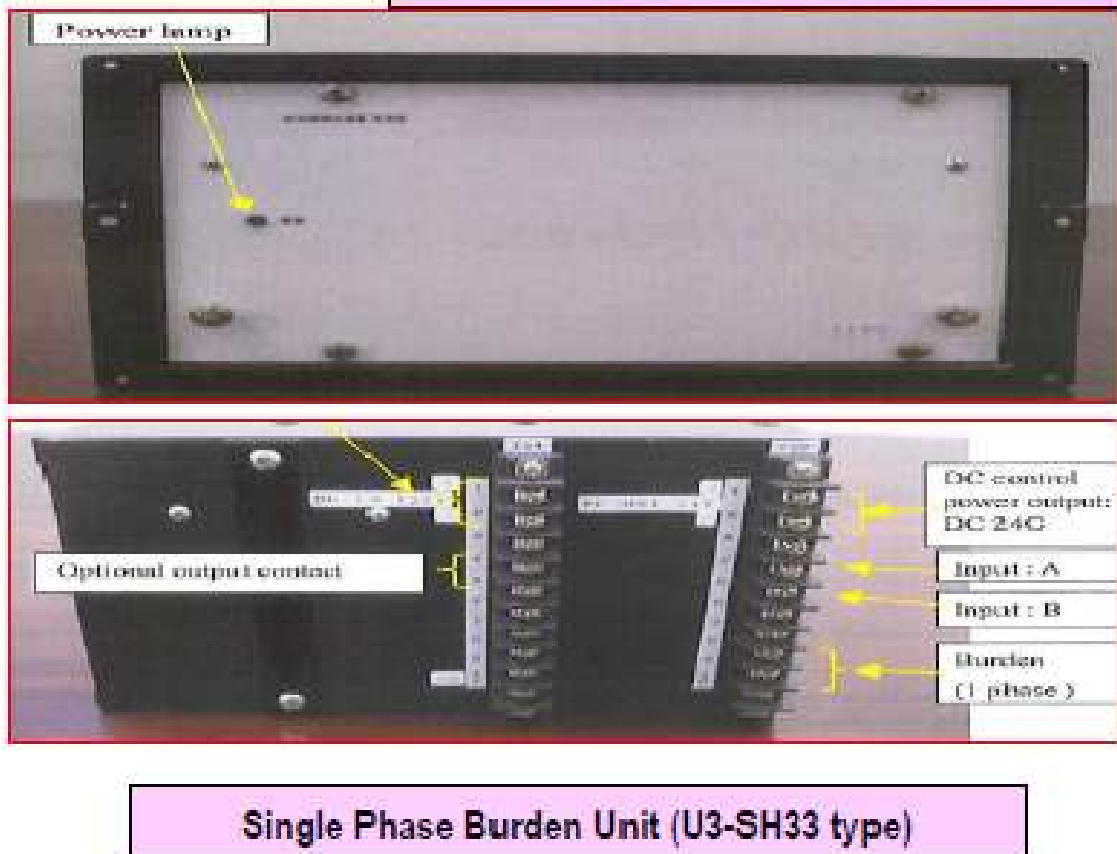


Setting values of detecting unit

1. Base frequency(50Hz) : 63V or 95V±5%, adjustable range: 0~120%, ▶ 150% of rated voltage 63.5V
2. 1/3 of base frequency: 32V±10%
3. 1/5 of base frequency : 19V±10%
4. Operating time: 350 ms
5. Release time: 500 ms
6. Control voltage: DC110V

Burden unit 2 Ω* 6 pieces (total 0.33Ω) parallel connection

Fig. 4: Information for adjusting FDSD



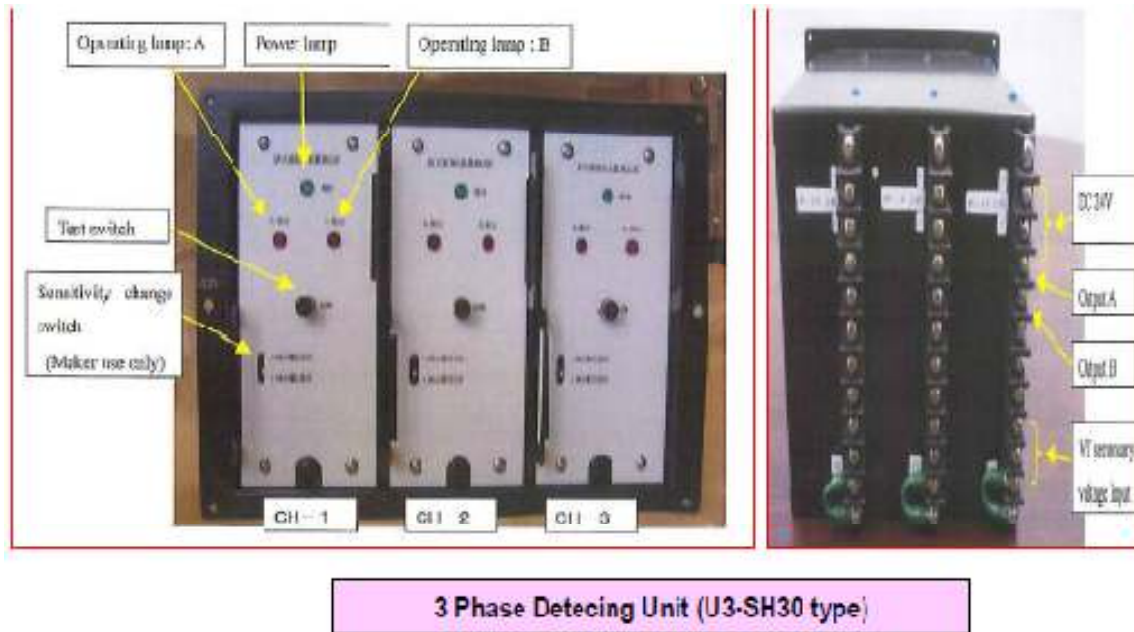


Fig. 5: Picture of seeming figure of FDSD

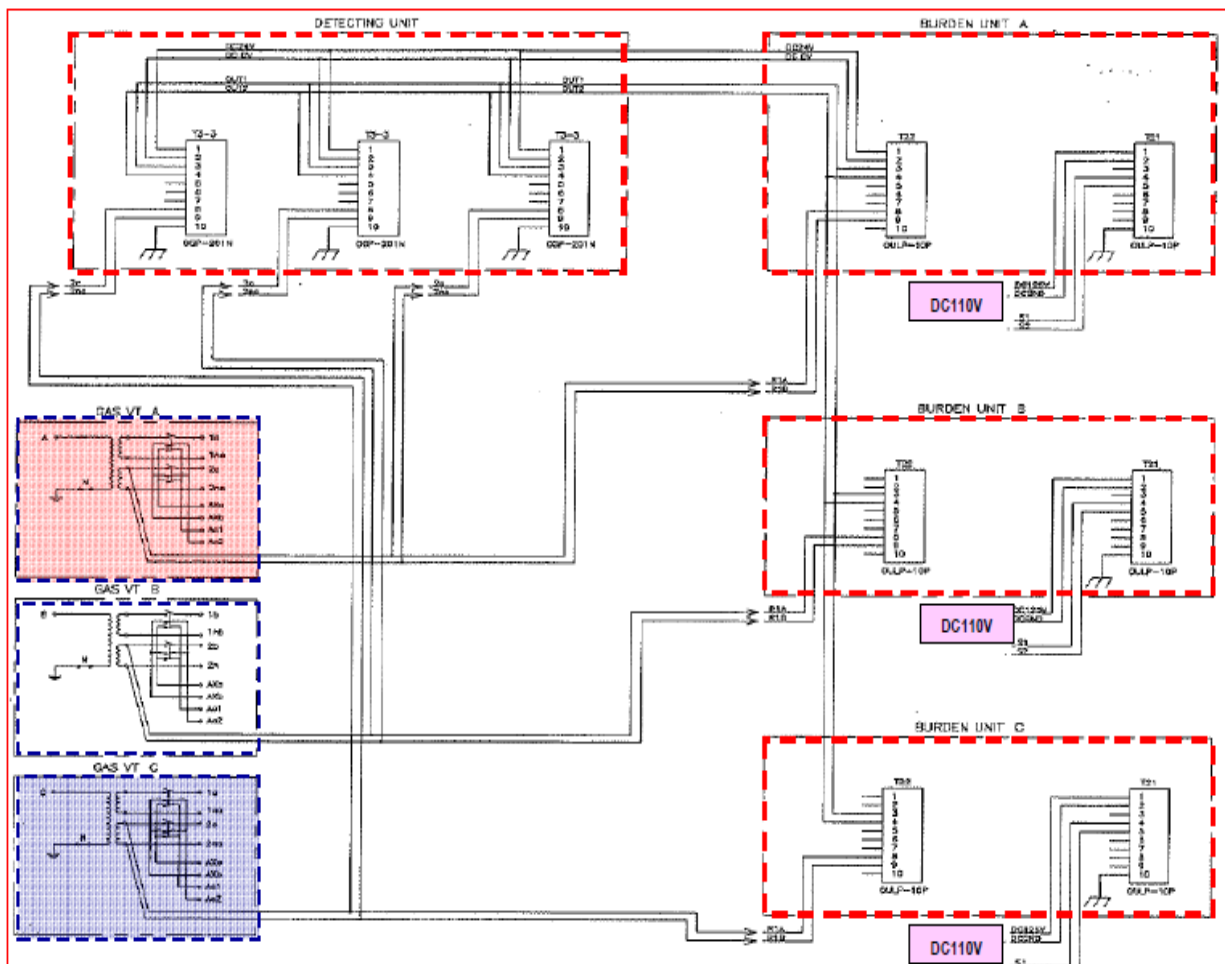


Fig. 6: Diagram of three phase FDSD connection

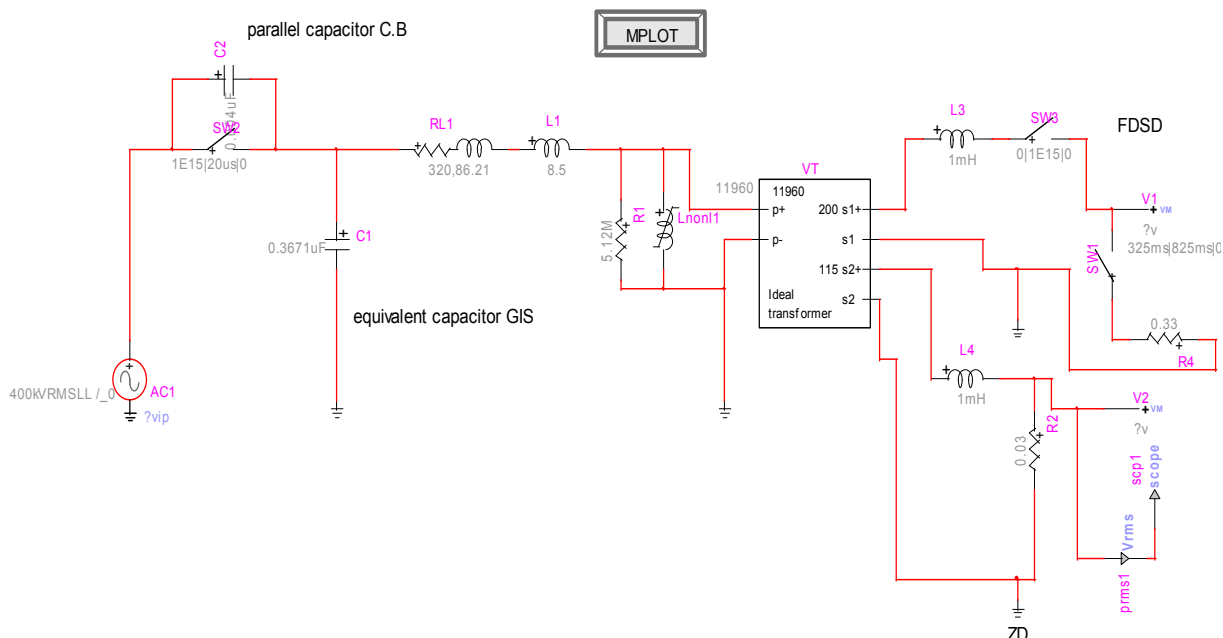


Fig. 7: EMTP model for survey ferroresonance with FDS+ZD

substation in different studied conditions that are as a result of summation of existing parameters which is studied in bellow waveforms. Also in this circuit, one VT with prime voltage of 400 kV and secondary voltage of 105 V is used for simulation and at last ZD and FDS+ZD equivalent circuit for damping probability of ferroresonance due to 4000 pF capacitor parallel with CB are put (Shoup *et al.*, 2011; Piasecki *et al.*, 2009):

- If $C1 = 4000 \text{ pF}$ and $C2 = 3820 \text{ pF}$ (for VT of bus 1)
Which capacitor:

$$C2 = (53.2 + 5.6 + 5.6 + 2 + 6.5) * 52.4 = 3820$$

- If $C1 = 4000 \text{ pf}$ and $C2 = 7669 \text{ pf}$ (for VT bus)
Which capacitor:

$$C2 = (53.2 + 5.6 + 7.05 + 7.2 * 9 + 2 + 7.2 + 6.5) * 52.4 = 7669$$

The structure of gas switchers generally act like a capacitor (energized conductor-gas insulator-grounded body). Also because of the mentioned reasons in high voltages, capacitors parallel with breaker contacts are used. Capacitor parallel with breaker contacts are in series with GIS switcher capacitor, therefore always there is a path for transmission of capacitor current, even when the breaker is in open state. This current cause the voltage division between two capacitors and whatever the ratio of breaker parallel capacitor to GIS capacitor is larger (lower impedance), voltage after

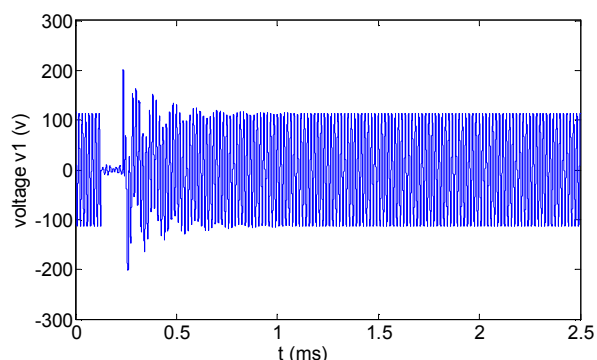


Fig. 8: Voltage waveform of VT secondary voltage in damping ferroresonance (V1)

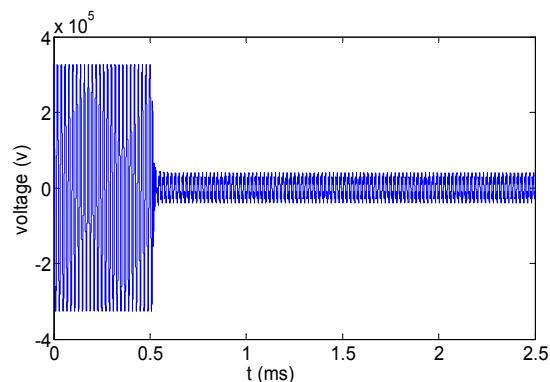


Fig. 9: Voltage waveform of VT primary

circuit breaker and on the bus bar will be larger. GIS circuit breaker existing in mentioned substation has two 2000 pf capacitors parallel with breaker contact that the

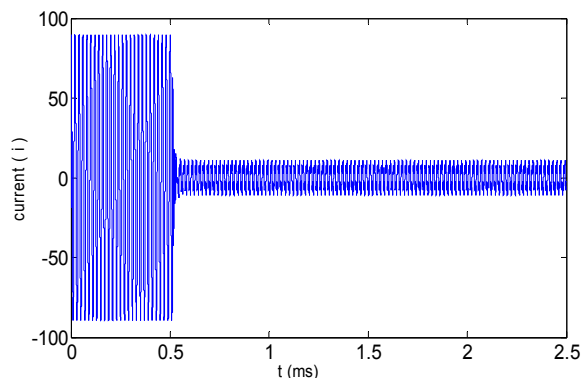


Fig. 10: Current waveform of VT primary

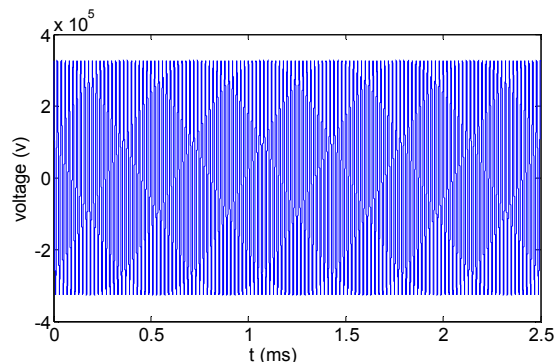


Fig. 13: Used voltage source waveform in simulated diagram with EMTP

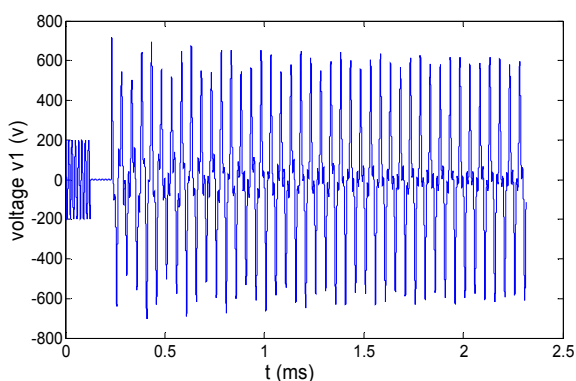


Fig. 11: VT secondary voltage waveform in presence of ferroresonance (V1)

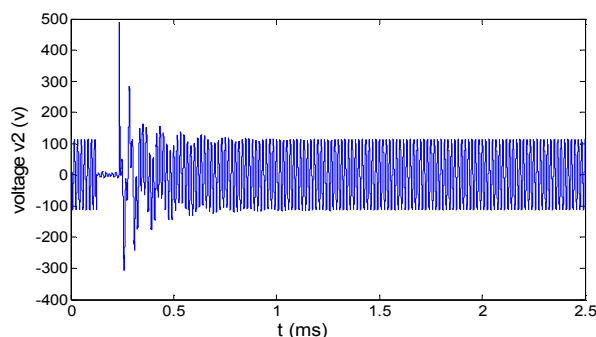


Fig. 14: VT secondary voltage waveform in damping ferroresonance (V2)

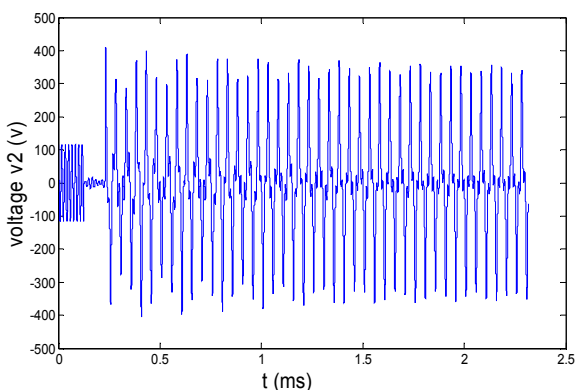


Fig. 12: VT secondary voltage waveform in presence of ferroresonance (V2)

equivalent capacitance will be 4000 pf and can cause the ferroresonance on equipment's like VT. Different producers of gas switchers use these capacitors to increase the operation of their circuit breakers (Abbasi and Seifi, 2009; Piasecki *et al.*, 2009).

One effect of ferroresonance due to breaker parallel capacitor is heating and burning VT in Karoon 4 power plant 400 kV GIS substation that is one of problems in such substation that their equipment are made by Hyundai company and other several company.

CONCLUSION

In this study ferroresonance phenomenon on voltage measuring transformer in real 400 kV GIS substation (karon 4 power plant) has been studied. After simulation, Fig. 7 to 9 show primary and secondary voltage waveforms of VT and Fig. 10 shows primary current of VT for bus number 1. Figure 11 and 12 show secondary voltage waveform of VT in presence of ferroresonance for bus 1 and bus 2 in sequence. Figure 13 shows the source used in simulated diagram with EMTP and Fig. 14 shows the secondary voltage waveform of VT in damping ferroresonance for bus 2. The corresponding model has been presented and for different conditions, simulation proved ferroresonance on VTs of bus 1 and 2. To eliminate this phenomenon, ZD+FDSD damper circuit had been designed and added to model, results of simulation showed success damping of these ferroresonance oscillations.

REFERENCES

- Abbasi, A. and A. Seifi, 2009. Fast and perfect damping circuit for ferroresonance phenomena in coupling capacitor voltage transformers. J. Electr. Pow. Compo. Sys., 37: 393-402.

- Hyundai Reports, 2011. Ferroresonance of VT. Hyundai Heavy Industries Co., Ltd., Electro Electric System Div./Electro-Mechanical Research Institute.
- Jacobson, D.A.N., 2003. Examples of Ferroresonance in a high voltage power system. Proceeding of the IEEE Power Engineering Society General Meeting, Vol. 2.
- Mohseni, H., J. Jadidian, A.A. Shayegani-Akmal, E. Hashemi, A. Naieny and E. Agheb, 2008. In-situ insulation test of 400 kV GIS. IEEE T. Dielect. El. In., 15(5): 1449-1455.
- Piasecki, W., M. Stosur, M. Florkowski, M. Fulczyk and B. Lewandowski, 2009. Mitigating ferroresonance in HV inductive transformers. Proceeding of the Presented at the International Conference on Power System Transients (IPST'09), Kyoto, Japan, June 3-6.
- Qing, L. and Z. Yufeng, 2008. Influence of switching conditions on very fast transient over-voltage in 500kV gas insulated substation. Proceeding of International Conference on Electrical Machines and Systems (ICEMS 2008), pp: 4451-4454.
- Shahabi, S., D. Babazadeh, R.E. Shirvani and M. Purrezagholi, 2009. Mitigating Ferroresonance in Coupling Capacitor Voltage Transformers with Ferroresonance Suppressing Circuits. Proceeding of IEEE EUROCON 2009. St.-Petersburg, pp: 817-822.
- Shoup, D., J. Paserba, D. Sullivan, P. Bolin and R. Whiteside, 2011. Ferroresonance Analysis of 500 kv Gas-Insulated Substation. Mitsubishi Electric Power Products, Inc. (MEPPI), Warrendale, PA 15086, USA.
- Tseng, K.H. and P.Y. Cheng, 2011. Mitigating 161 kV electromagnetic potential transformers' ferroresonance with damping reactors in a gas-insulated switchgear. IET Gener. Transm. Dis., 5(4): 479-488.