

## Research Article

### Survey of Induced Voltage and Current Phenomena in GIS Substation

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**Abstract:** Induced capacitive voltage and current in high voltage GIS substation is one of the most significant phenomena that may have made some problems in this substation operation. At this study the various equipment of 420 KV Karoon4 substations such as powerhouses, input and output lines, bus-bar and bus-duct have simulated by applying EMTP-RV software. Then with the different condition of single-phase and three-phase faults on the lines in critical conditions, capacitive induction voltage and current by parallel capacitor with circuit breaker is surveyed. The results show the value of this induced current and voltage and that this critical conditions the breakers and disconnect switches must be able to interrupt this value of current.

**Keywords:** Gas Insulated Substation (GIS), induced current, induced voltage

#### INTRODUCTION

Parallel capacitors with breaker contacts have been used to improve the performance of power circuit breaker for interrupting the single-phase to ground fault near the circuit breaker in GIS with the voltage rate of 300 KV and above. After a single-phase fault occurs, the return voltage amplitude, which comes from the fault side and can be increased to twice of its nominal value, creates value of current that the circuit breaker would not be able to interrupt it. Parallel capacitor is used to produce a time delay for removing of transient state which is a result of fault. The time delay is determined by the following equation:

$$t_{dl} = c.z$$

where,

C = The parallel capacitance with circuit breaker

Z = The line surge impedance

However, the existence of parallel capacitor would produce some problems. A value of voltage and current is induced to the network after the power circuit breaker interruption and due to the capacitor existence. Disconnect switches must be able to interrupt this value of current. In the study, this crucial phenomenon has been studied with the modeling of 420 KV Karoon4 GIS substation (Kumar *et al.*, 2011; Hyundai Heavy Industrial, 2011). In previous studies, various methods have been used to model the substation equipment specially bus bar and bus duct. Transmission line model

with distributed parameters and cable model are some examples of modeled bus bar and bus duct in previous studies. Each of these methods has advantages and disadvantages that some of them are mentioned below: (Tavakoli *et al.*, 2009; Liu and Yufeng, 2008):

- Ignoring the damping and losses
- Ignoring dependency of parameters to frequency
- Disregarding the interaction between conductor and enclosure
- The complexity of calculating the parameter in some installing bus bar in bus duct conditions

The model  $\pi$  has been used to model GIS busbar and busduct in this study due to the mentioned reasons and the model would be described in detail.

#### INTRODUCING OF KAROON 4 SUBSTATION

Karoon 4 GIS substation has the voltage rate of 420 KV and double bus bar arrangement with by-pass disconnect switch. This substation is connected to the power units with 12 additive single-phase transformers in which the capacity of each is 100 MW. The substation output is connected to the network with 4 overhead 420 KV lines with double-bundle arrangement. Single-line diagram of mentioned substation has been shown in Fig. 1. As can be seen, the output lines include: Lordegan double-circuit lines with the length of 48 Km and Karoon 3 double-circuit lines with the length of 300 Km.

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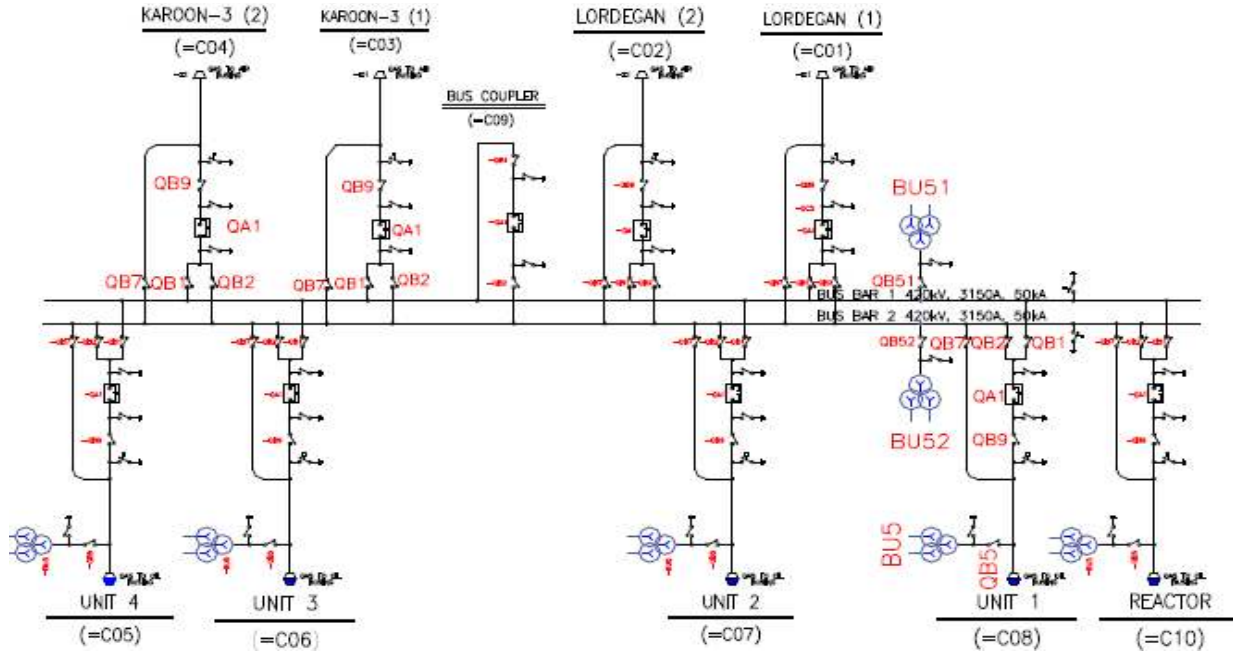


Fig. 1: Single line diagram of karoon4 420 KV GIS

### GIS EQUIPMENT MODELING

Busbar and busduct are some of the effective elements on capacitive voltage and current induction phenomenon in GIS substations. In this study, double-phase  $\pi$  model in EMTP-RV software has been used to model the substation section. In this model, one phase is allocated to busbar and the other phase is appropriated to busduct (external enclosure). The values of self and mutual inductance and capacitance have been calculated to consider the coupling effect between bus bar and bus duct. These values have been put in  $\pi$  model. According to the Eq. (1), the value of mutual capacitance between busbar and busduct is  $43.25 PF/m$ . The mutual value of inductance is considered zero. Spacers, also, have capacitance value of  $12.26 PF/m$ . Equation (2) and (3) have been used to measure the self capacitance and inductance (Kondalu *et al.*, 2001; Thompson, 1999):

$$C_{12} = C_{21} = \frac{2\pi\epsilon_0\epsilon_s}{\ln\left(\frac{a_1}{a}\right)} l \quad \text{F/m} \quad (1)$$

$$C = \frac{2\pi\epsilon_0\epsilon_s}{\ln\left(\frac{d}{a} + \sqrt{\frac{d^2}{a^2} - 1}\right)} l \quad \text{F/m} \quad (2)$$

$$L = \frac{\mu_0}{2\pi} \ln\left(\frac{a_1}{a}\right) l \quad \text{H/m} \quad (3)$$

where,

d = The distance between enclosure center and ground

a = External radius

$a_1$  = Internal radius and l is length of enclosure

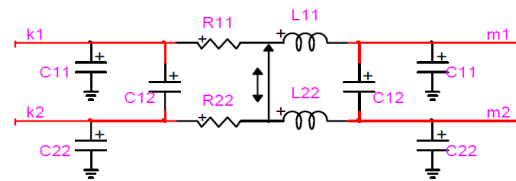


Fig. 2:  $\pi$  equivalence model for GIS busbar and busduct

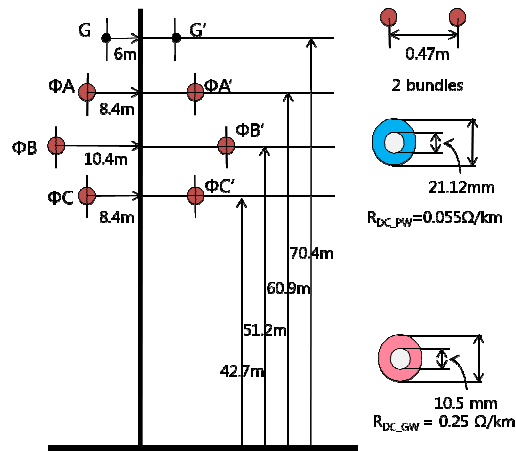


Fig. 3: The transmission line arrangement

The double-phase  $\pi$  model, which has been used in this study, is shown in Fig. 2. A series model of inductor with resistor has been used for reactor and, surge arresters have also been modeled as non-linear resistance. FD model was used in the purpose of transmission lines modeling. The transmission line arrangement is shown in Fig. 3.

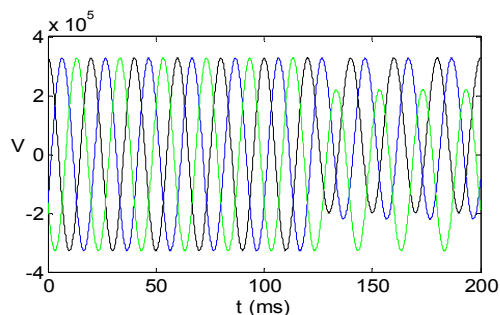


Fig. 4: Induced current with no fault condition (A-mS)

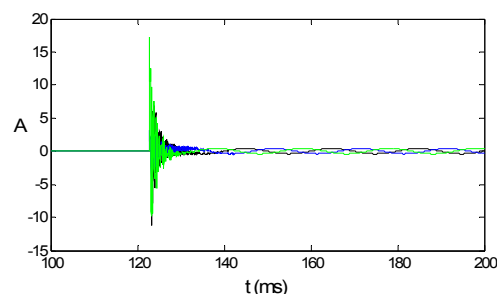


Fig. 7: Induced current to the network after single-phase to ground fault removing (A-mS)

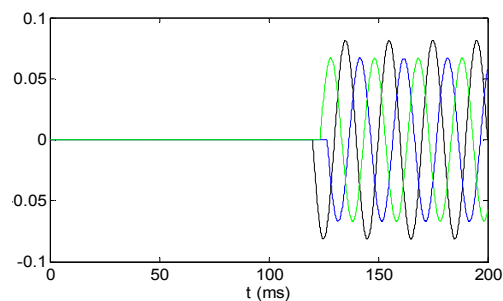


Fig. 5: Induced voltage with no fault condition (V-mS)

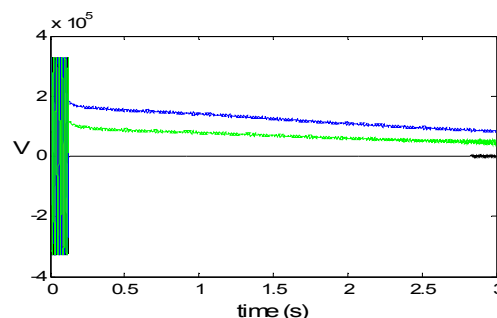


Fig. 8: Induced voltage to the network after single-phase to ground fault removing (V-mS)

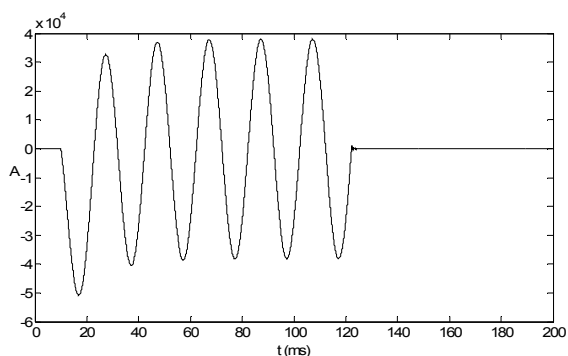


Fig. 6: Single-phase to ground fault current on transmission line (A-mS)

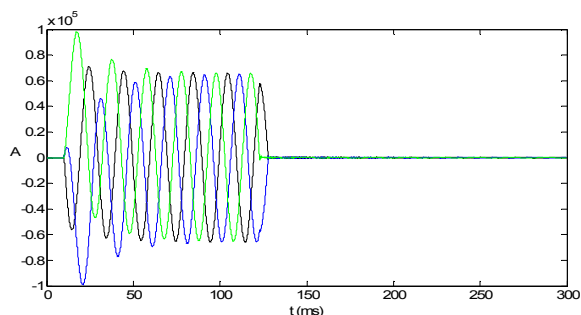


Fig. 9: Three-phase short-circuit fault current on transmission line (A-mS)

### SIMULATION RESULTS

In this section, first, the network is considered in no-fault condition. The generators are disconnected from the network and the network is supplied from the line side. When the line side circuit breaker is opened, a value of voltage is transferred to bus bar through capacity or which is paralleled with circuit breaker. The voltage value that is produced on bus bar will be less than the primary voltage due to the voltage division between circuit breaker capacitor, other circuit breakers and the coupled capacitor which between GIS and ground. When the circuit breaker is opened, a value of current is also induced to the network due to the existence of a capacitor which is paralleled with the

circuit breaker contact. The current and voltage values are similar to the measured value during launching the substation. These values are shown in Fig. 4 and 5. Thereafter, the fault current value and capacitive voltage and current induction phenomena are presented in different fault conditions.

#### Single-phase to ground fault on transmission line:

There is a single-phase to ground fault at 10 ms in 26.6 Km away from the beginning of Karoon 3 line then the begin and end circuit breakers of the line start interrupting the line from the network at 120 ms. This event has been simulated and the fault current waveform is shown in Fig. 6. As can be seen, the value of fault current pick is 51 kA. A value of current is

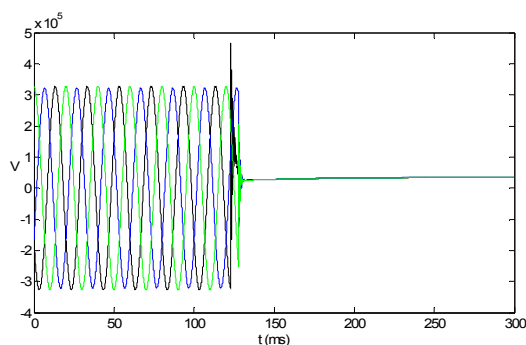


Fig. 10: Induced current to the network after three-phase short-circuit fault removing (A-mS)

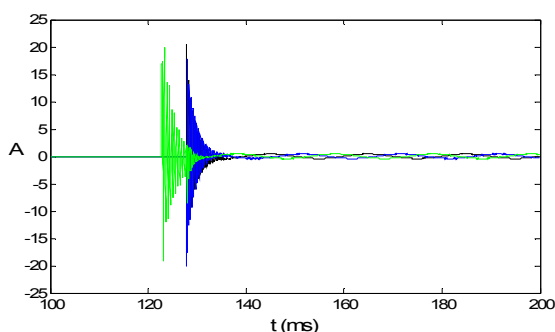


Fig. 11: Induced voltage to the network after three-phase short-circuit fault removing (V-mS)

Table 1: Calculation summary of induced current and voltage in different conditions

		4000 pF	
		Initial	Steady
No fault	Induced current (A)	0.08	0.08
	Induced voltage (kV)	327	262
Single-phase to ground	Induced current (A)	18	0.41
	Induced voltage (kV)	230	9.20
Three-phase short-circuit	Induced current (A)	21	0.48
	Induced voltage (kV)	467	2.10

passed through the parallel capacitor with circuit breaker due to the interrupting of begin and end circuit breakers of the line and it is induced to the network. This induced current is shown in Fig. 7. As it is clear, the current value reaches to 0.41 amperes in steady state. The induced voltage value is completely similar to the measured value in the substation. This value is shown in Fig. 8.

**Three-phase to ground fault on transmission line:** A three-phase short-circuit fault occurs at 10 ms in 26.6 Km away from Karoon3 line outset. The begin and end circuit breakers of the line interrupt the line form the network at 120 ms This event has been simulated and the fault current waveform is shown in Fig. 9. As can be seen, the fault current pick value is 64 kA. A current value is passed through parallel capacitor with circuit

breaker due to the interruption of begin and end circuit breakers of the line. Then, this current value is induced to the network that is shown in Fig. 10. As can be seen, the current value reaches to 0.48 amperes in steady state. The induced voltage is, also, shown in Fig. 11. As it is clear from Fig. 11, the obtained voltage value is quite similar to the measured value of the substation. The results in different conditions are shown in Table 1.

## CONCLUSION

In this study, capacitive current and voltage induction phenomena in 420 KV Karoon4 GIS substation were studied and simulated in EMTP-RV software. As it was seen, with the interrupting of all kinds of faults, a value of current passed through the parallel capacitor with circuit breaker in this substation. In this case, a value of voltage, also, was induced to one side of capacitor which was located in line side. The results indicate that the value of remnant current, which is due to parallel capacitor and coupled capacitor of system with the ground, cannot exceed 0.5 amperes for all conditions. So the disconnect switches that are used in the substation must be able to interrupt this current value. However, it must be considered that the results were obtained in the worst conditions and these conditions must be noticed during the testing and designing of equipment. The complexity of capacitive current and voltage induction phenomena in high voltage GIS substation were shown in this research. Consequently, in order to design and appropriate choose of disconnect switch, studying about this phenomenon is an essential issue so that without having enough knowledge, the substation operation would face with problem.

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