2nd INTERNATIONAL CONFERENCE ON
RESEARCH IN SCIENCE AND TECHNOLOGY
Istanbul-Turkey 14 March 2016
RSTCONF
دومین کنفرانس بین المللی
پژوهش در علوم و تکنولوژی
ترکیه - استانبول ۲۴ اسفند ۱۳۹۴

Examining the impact of parallel compensators SVC and STATCOM on distance relays functioning in transmission network

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Abstract

Modern systems of energy transfer due to large loads with high voltages who can drop measures should be used to solve this problem. One of the ways FACTS elements such as voltage regulation of series capacitors and SVC which in addition to increasing the capacity of transmission lines, stability and crafts balancing losses is three-phase voltages. But FACTS elements can be performance of protection schemes, including distance protection for transmission lines used, damage. Relay impedance measurement along with errors that caused the earth fault resistance, the condition of the system error, the effects of parallel and series capacitors FACTS, etc. are elements each of which can increase the range and reduce relay that resulting in the loss of harmony between the distance relays. Therefore, it is necessary to examine the effect of various elements on the distance relay and solutions to them be used.

Keywords: svc, statcom, facts, distance relays

Introduction

The use of flexible alternating current transmission (FACTS) devices in power systems for increasing the power transfer and providing the optimum utilization of system capability by pushing the power systems to their limits has been of worldwide interest in the recent years. Literature reviews indicated that FACTS devices introduce new power system dynamics that must be analyzed by the system protection engineer [1]. These dynamics can be summarized as the following:

1) the rapid changes in system parameters such as line impedance, power angle and line currents;

2) the transients that are introduced by the associated control action;

3) the harmonics introduced into the adjacent ac power system.

Because of these concerns, the protection relays requirements cannot be clearly defined until a particular FACTS strategy is modeled and analyzed within its power system. Such protection requirements are

1) a need for an adaptive relay characteristic as the system parameters and configuration are rapidly changed by the FACTS devices;

2) assurance that the various protective relays can accommodate different power system contingencies and control modes of the FACTS devices;

3) specifying the operating times and tripping schemes of the protection relays.

There exists literature on the performance of the protection for a power system containing FACTS devices [1]–[5]. The work in [1] addressed the system protection requirements for a power system containing TCSC-based (thyristor controlled series capacitor) FACTS device. The work reported in [2] considered the performance of a distance relay in a system utilizing three-phase static shunt-reactor compensation of the linear and saturable types. In [3], an extensive study of distance protection was applied to various power system configurations using an interconnection involving four reactor linear shunt compensators. The study presented in [4] discussed the limitations imposed on the applicability of distance relay mho elements in the protection of MOV-protected series-compensated transmission lines. The study in [5] proposed an adaptive protection for transmission lines employing advanced series compensated (ASC) transmission lines. In conclusion, the literature studies and the operating experience with static compensators (SVC) and thyristor controlled series capacitor (TCSC) have demonstrated the need to modify protective relay operating characteristics. Among the different types of FACTS devices, the static var compensators (SVCs) are devices that control the voltage at their point of connection to the power system by adjusting their susceptance to supply or absorb reactive power [6], [7]. In general, SVCs are characterized by their ability to rapidly vary the reactive output to compensate for changing system conditions [8], [9]. The development in power electronic devices such as gate turn off devices (GTOs) allows implementation of the so-called advanced static var systems (SVS). The static synchronous compensator (SSC or STATCOM) is an example of the advanced SVS. The STATCOM consists of three-phase sets of several gate turn-off switch-based valves and a DC link capacitor and controller thus replacing the conventional reactive power compensators. The objective of this paper is to analyze and investigate the impact of midpoint compensation using a STATCOM on the performance of impedance-based protection relays under normal operation and fault conditions at different load power angles. The paper begins with the necessary derivation of the mathematical equations used in the analysis of a typical interconnection with midpoint STATCOM and protected by MHO distance protection. A computer program based on these equations was developed to investigate the response of the distance relay under normal and fault conditions with and without the STATCOM. The results are also verified using the EMTDC simulation program [10]. Due to the increasing consumption of electrical energy generation, use of FACTS elements to increase network capacity and power handling. With the installation of such equipment in the transmission network increasing to evaluate its effects on other network equipment and protective components (eg distance relay) is required. Using a powerful simulation tools like the above-mentioned effects can be studied PSCAD Minex software. Because rapid response equipment, FACTS, and the reaction of the equipment in the system parameters to investigate the protective system with the necessary equipment with the use of software as a simulator PSCAD powerful, can be studied this. Modern systems of energy transfer due to large loads with high voltage drops that measures should be used to solve this problem. One way of FACTS elements such as voltage regulation, use of series capacitors and SVC which in addition to increasing the capacity of transmission lines and balancing stability and help the casualties are three-phase voltages. But FACTS could elements performance of conservation areas such as distance protection for transmission lines used, damage. Relay with impedance measurement errors caused by ground fault resistance, a pre-fault system of parallel and series capacitors FACTS elements and requirements. Each of these relays can be used to increase and decrease, resulting in the loss of co-ordination between the distance relays. Therefore, it is necessary to examine the effect of various elements on the distance relay and solutions to them be used. The aim of this study was to analyze and study the effect of compensation parallel lines using SVC and STATCOM installation locations such as the mid-point on the apparent impedance measured in the area of protective relaying and fault tolerance for different values the length of the transmission line, is under different errors.

In this section SVC effect on the impedance measured by the distance relay for single phase to ground fault resistance at zero and non-zero error is investigated.

SVC at the beginning of the line:

$$Z_{appaerntA} = pZ_{۱L} + \frac{۳R_f}{\frac{I}{I_{۱}} + [۲C_{۱} + C_{۰}(۱ + ۳K_{۰})]}$$

SVC at the mid-point line:

$$Z_{appaerntA} = pZ_{۱L} + \frac{C_F + ۳R_f}{C + ۲C'_{۱}C_{۱} + C'_{۰}C_{۰}(۱ + ۳K_{۰})}$$

SVC at the end of the line:

Calculate the apparent impedance measured in the presence of STATCOM:

In the STATCOM effect on the impedance measurement will be reviewed. In this section, all calculation relations in the presence of STATCOM are calculated.

STATCOM at the beginning of the line:

$$Z_{appurrent} = pZ_{۱l} + \frac{۳R_f}{C + ۲C_{۱} + C_{۰}(۱ + ۳k)}$$

models Used in dynamic simulation:

Post the first transmission line with a voltage of 400 kV and short-circuit level GVA 20 model. E end of the line is controlled by a voltage source 384 kV (400 × 96/0) with short circuit GVA 10 model. 400 kV transmission line Zanjan, Tabriz with 30 π equivalent circuit section with a length of 10 km (300 kilometers) to establish the possibility of error handling is modeled. Other characteristics of the network, just like the information presented in the previous section is intended. The distance relay is placed at bus Zanjan. To measure the impedance from the perspective of the relay, an effective amount of voltage and current signals in the principal component (50 Hz) and remove the DC offset resulting from flow changes when an error is calculated. Jet necessary block this calculation is available in the library in PSCAD.

Transmission line model:

For the protection of power system frequency behavior of the system is concerned, π model for transmission line of appropriate accuracy. Π model is shown in the figure below, the values of resistors and inductors and capacitors in series two head based on the information entered by the user is calculated. Coupled model is necessary to consider the effect of zero sequence impedance.

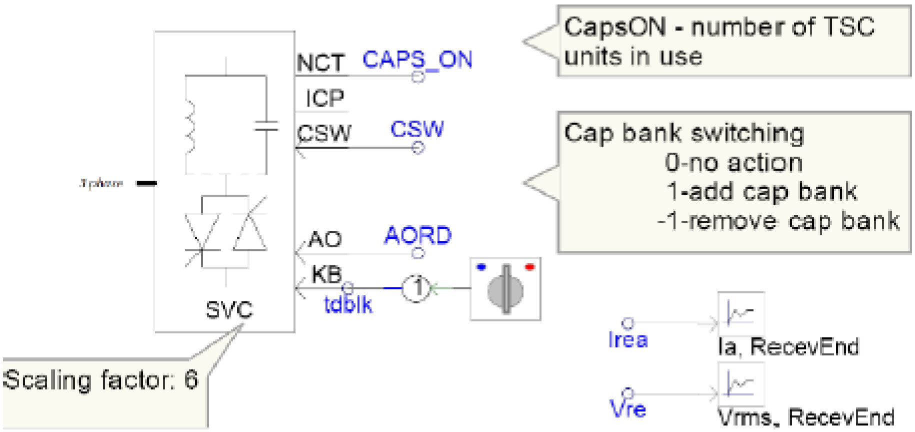

Fig 1. SVC used in PSCAD

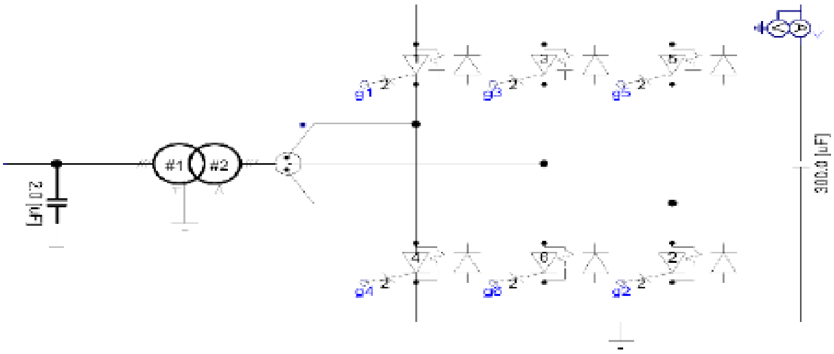

Fig 2. STATCOM used in PSCAD

Single phase error:

Before connecting devices, SVC and Statcom seen from the beginning of the line resistance and reactance values of R = 403.44 respectively and was X = 89.51 with single- phase to ground fault on these parameters, the values of R = 4.57 and X = 45.63 is reached after debugging again returned to the previous value. Also in this case, the changes seen since the beginning of the resistance and reactance line is as follows.

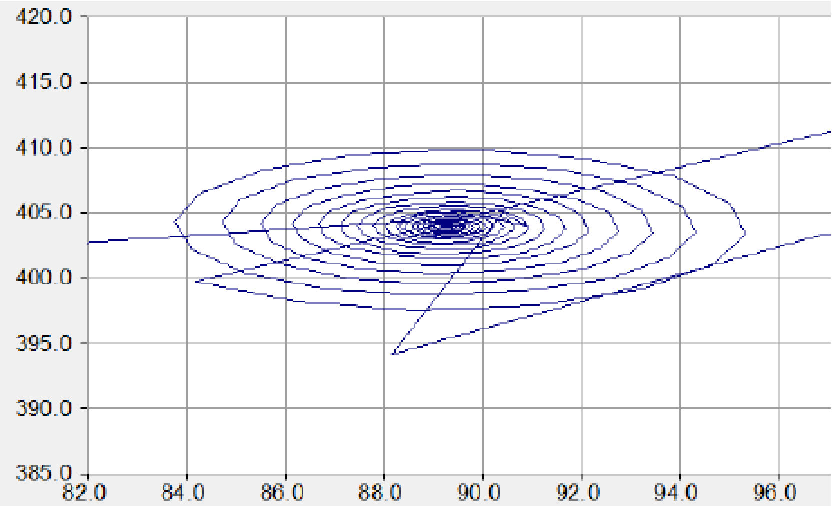

Fig 3. Converging resistance and reactance seen from the beginning of the line in normal mode without error

Figure 3 shows how converging resistance and reactance seen from the beginning of the line in normal mode without error .

Three-phase fault:

Before connecting devices, SVC and Statcom seen from the beginning of the line resistance and reactance values of R = 403.96 respectively and was X = 89.45 with a three-phase to ground fault on these parameters, the values of R = 1.74 and X = 45.38 is reached after debugging again returned to the previous value. Also in this case, the changes seen since the beginning of the resistance and reactance line is as follows.

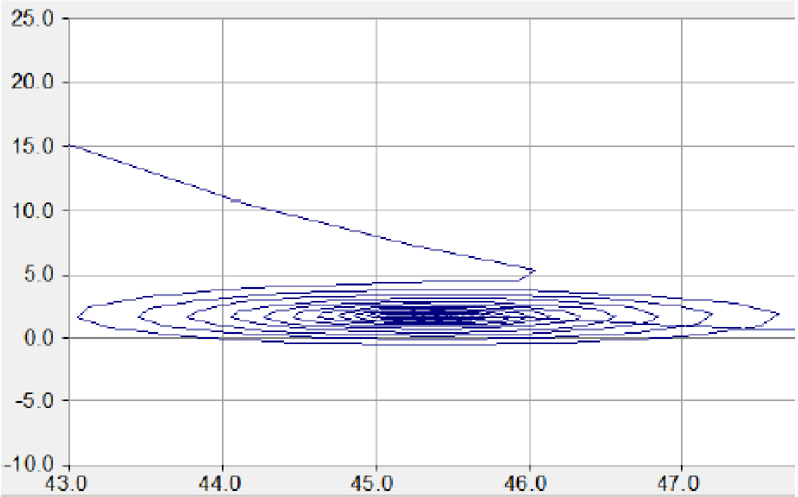

Fig 4. Converging resistance and reactance parameters

Three-phase fault with the way the changes and converging resistance and reactance parameters seen in Figure 4.

after SVC connection

Table 1. The impedance measured at the end of the line of sight relay SVC

impedance		SVC	Rf	short circuit Location
R	X			
۱۳۷/۷۸	۱/۹۳	Vref=1	۲۰۰	**beginning**
۱/۳۵	۴۵/۲۰	Vref=1	۰	**middle**
۱۸۸/۶۰	۲۷/۷۰	Vref=1	۲۰۰	
۱/۳۸	۹۰/۷۳	Vref=1	۰	**End**
۱۰۱/۷۵	۶۶/۴۰	Vref=1	۲۰	
۲۹۸/۸۴	۳۲/۸۹	Vref=1	۲۰۰	

After connecting STATCOM

Table 2. The measured impedance with STATCOM at the end of the line of sight relay

impedance		Statcom	Rf	short circuit
R	X			Location
۱۴۰/۴۵	۲۸/۴۱	Vref=0.9	۲۰۰	**beginning**
۲/۰۹	۴۵/۶۶	Vref=0.9	۰	
۱۸۴/۹۰	۷۸/۸۲	Vref=0.9	۲۰۰	
۱/۲۴	۹۰/۷۳	Vref=0.9	۰	**End**
۹۴/۹۷	۴۸/۸۱	Vref=0.9	۲۰	
۲۷۹	۱۵۹/۴۳	Vref=0.9	۲۰۰	

Two phase to ground fault:

Before connecting devices, SVC and Statcom seen from the beginning of the line resistance and reactance values of R = 403.96 respectively and was X = 89.45 with Single phase to ground fault on these parameters, the values of R = 3.04 and X = 43.73 is reached after debugging again returned to the previous value.

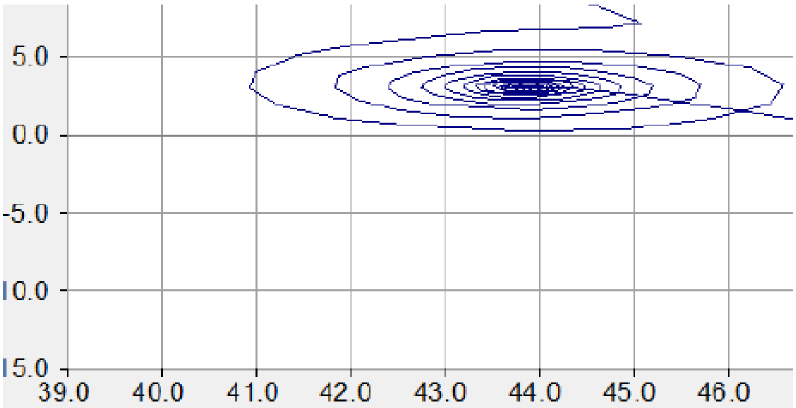

Fig 5. Changes and converging resistance and reactance parameters of two-phase fault

after SVC connection

Table 3. SVC impedance measured at the end of the line of sight relay

impedance		**SVC**	**Rf**	**short circuit Location**
R	X			
۹۰/۱	۳۷/۶۱	Vref=1	۲۰۰	**beginning**
۳/۳۵	۴۳/۴۹	Vref=1	۰	**middle**
۱۵۲/۰۸	۸۰	Vref=1	۲۰۰	
۵/۸۴	۸۹/۸	Vref=1	۰	**End**
۱۰۳/۴۴	۵۹/۴۵	Vref=1	۲۰	
۳۰۰/۱۱	۳۲/۳۱	Vref=1	۲۰۰	

After connecting STATCOM

Table 4. The measured impedance with STATCOM at the end of the line of sight relay

impedance		**Statcom**	**Rf**	**short circuit Location**
R	X			
۸۳/۶۲	۴۷/۲۶	Vref=0.9	۲۰۰	**beginning**
۳/۴۵	۴۴/۱	Vref=0.9	۰	**middle**
۱۲۹/۹۶	۱۰۷/۲۴	Vref=0.9	۲۰۰	
۳/۹۱	۸۹/۲۷	Vref=0.9	۰	**End**
۱۰۳/۶۴	۶۳/۵۲	Vref=0.9	۲۰	
۲۷۱/۳۹	۱۶۰/۴۸	Vref=0.9	۲۰۰	

Fault of phases together:

Before connecting devices, SVC and Statcom seen from the beginning of the line resistance and reactance values of R = 403.59 respectively and was X = 89.33 with two-phase errors in these parameters, the values of R = 1.52 and X = 45.19 is reached after debugging again returned to the previous value.

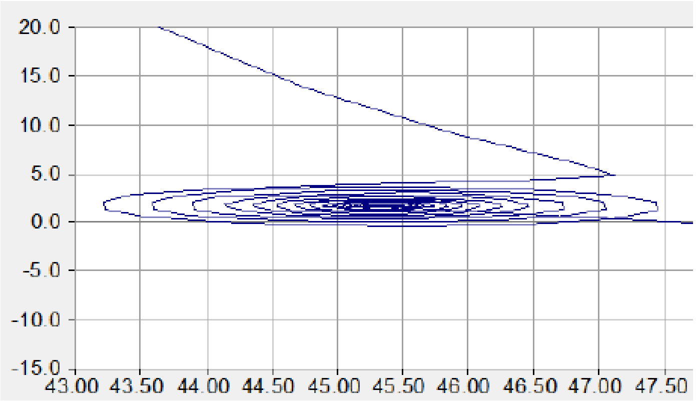

Fig 4. Changes and converging resistance and reactance parameters seen

after SVC connection

table 5 . SVC impedance measured at the end of the line of sight relay

impedance		SVC	Rf	short circuit Location
R	X			
۸۳/۸۱	-۰/۳۱۰	Vref=1	۲۰۰	**beginning**
۱/۷۶	۴۵/۱۳	Vref=1	۰	**middle**
۱۲۵/۵۲	۳۱/۴۸	Vref=1	۲۰۰	
۴/۲	۹۰/۵۲	Vref=1	۰	**End**
۶۰/۴۵	۷۷/۶۸	Vref=1	۲۰	
۲۴۶/۹	۴۳	Vref=1	۲۰۰	

After connecting STATCOM

Table 6 . The measured impedance with STATCOM at the end of the line of sight relay

impedance		Statcom	Rf	short circuit Location
R	X			
۸۵/۳۹	۹/۷۷	Vref=0.9	۲۰۰	**beginning**
۲/۰۷	۴۵/۲۶	Vref=0.9	۰	**middle**
۱۲۳/۰۹	۵۴/۷۶	Vref=0.9	۲۰۰	
۲/۵۷	۹۰/۴۷	Vref=0.9	۰	**End**
۶۲/۳۵	۷۰/۴۸	Vref=0.9	۲۰	
۲۳۲/۶۶	۱۲۵/۵۲	Vref=0.9	۲۰۰	

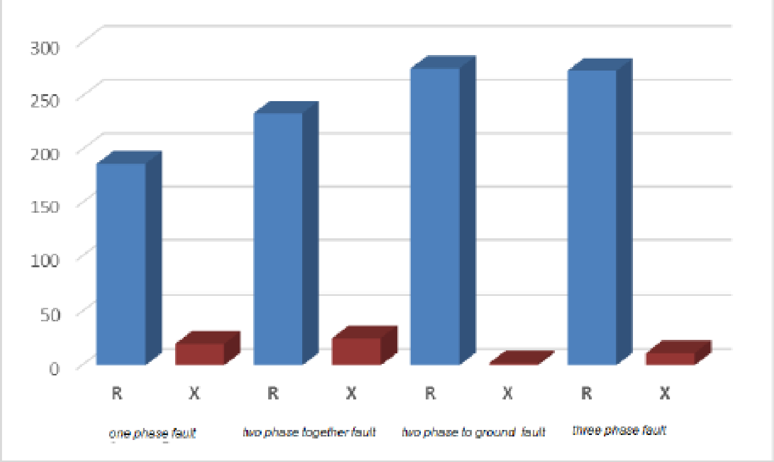

Fig 6. Resistance and reactance measurement errors of the relay during Single phase, two-phase-to-ground, two-phase together and three-phase

Conclusion

The purpose of this paper is to study the effects of compensation parallel lines in various locations using SVC and Statcom the apparent impedance measured at the point of relaying and practice of distance relay under fault phase to earth, phase me, two phase-to-ground and three phases. In this project, the impedance of the relay through the simulation using the software simulation of power system transient (PSCAD / EMTDC) was calculated and the effect on the studied parameters. Each of these relays can be used to increase and decrease, resulting in the loss of co-ordination between the distance relays. The simulation results show that in networks with SVC and Statcom, as this Advatbh distance relay closer, the errors caused by impedance seen by distance relay will be more and more the fault of the relay off, the impedance seen by the relay the greater the distance error. Also increase or decrease the range of impedance relay to the settings for the device intended to inject reactive power depends. Reactive power injected by the device, reducing the distance relay with impedance range encountered and the reactive power consumption by the device, increasing the distance relay will experience a range of impedance. The amount of voltage settings Adavt a great impact on the apparent impedance seen by the relay and the voltage reference amount intended to be greater, the greater the impedance seen. The effects depend on the type of error, the location of it and the network load.

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