



Received: 04 September 2019
Accepted: 12 December 2019
First Published: 17 December 2019

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ELECTRICAL & ELECTRONIC ENGINEERING | RESEARCH ARTICLE

IEC 60909 and ANSI standards comparison with ASCC based fault calculations of Iraqi power system

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Abstract: The calculation of short circuit (SC) current has to be accurate because of their importance in power protection system's design and to determine the capacity of the protective devices. Therefore, there are many standards and programs to estimate SC calculation. The aim of this paper is to provide further calculation methods' understanding for determining SC current in PSS/E program. Here, the characteristics of SC at the busbars of Al-Nassiriya power plant; with 400/132 KV local transformers; which is part of Iraqi power system is analyzed using PSS/E program methods such as automatic sequence fault calculation (ASCC), IEC 60909 and (ANSI) standards. The finding of results comparison between the three methods refers that IEC standard result was the most accurate one in subtransient current calculation. This paper concludes that IEC have the best method to be followed in subtransient current calculations for Iraq power grid expansion studies and planning.



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Yasar N. Lafta received the B.S. degree/University of Technology in 1990, MSc degree of Electrical engineering/the college of Electrical & Electronic Techniques (Baghdad) in 2011. She experienced 10 years work as researcher/Mechatronics department/University of Baghdad. Her current article focuses on comparative study between 3 methods of short circuit current calculation and recommended IEC standard to be applied to the Iraqi grid in case of modeling planned expansion.

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PUBLIC INTEREST STATEMENT

Calculating short-circuit current level is important for electrical power engineers to renew protection devices and assess stability. Several criteria have emerged to study fault current such as ASCC, IEC, and ANSI.

The electrical systems expansion and the calculation accuracy importance require the development of calculation programs to study the system performance explicitly. One of these programs is the PSS@E, which deals with all the criteria, taking into account the factors affecting current calculation.

ASCC calculates all faults related to each home bus before proceeding to the next one in the specified subsystem.

This research investigates a factual and realistic comparison of these standards using the PSS@E program for 400/132 kV Nasiriyah busbar which represents a part of Iraq electrical grid. The comparison shows proximity in results, but it is recommended to use ANSI when the system does not contain generators as machine reactance; however, when the system expansion is intended it is recommended to use the IEC because it is more accurate.

Subjects: Power & Energy; Systems & Control Engineering; Electrical & Electronic Engineering

Keywords: Nassiriya power plant; ASCC; ANSI; IEC; short circuit current

1. Introduction

Power Network represents dynamic system that may be a subject of various disturbances including short circuit (SC), which affects the performance of power system (Lakshmi Sankar & Mohamed Iqbal, 2015). Fault occurrence causes an increase of SC current creating undesirable impact on nearby parameters; protective devices malfunction and system stability. Within disturbance instant, protective equipment capacity must be proportional to disturbance level (Yousefikia, Gharibreza, & Baledi, 2015). Fault current and voltages of power system during disturbance are provided by SC calculations. SC modules are number of calculation algorithms to meet the various needs of SC analyses.

Applications of SC Modules are American National Standards Institute (ANSI)—C37 and International Electrotechnical Commission (IEC)—60909. They support conventional SC studies regardless of any specific standards. Output information of SC modules are essential in designing suitable protective relaying system, also to determine required interrupting capacity at each switching location.

ANSI/IEEE std. 141—Red Book—was introduced by ANSI in North America in 1986, which convey C37; the parent standard. The standard is related ultimately to SC current calculation but immediately to suitable protective devices selection (Kaloudas, Papadopoulos, Papadopoulos, Marinopoulos, & Papagiannis, 2010). ANSI in conforming with C37.5 1979 standard Calculates: symmetrical fault MVA, symmetrical fault current, asymmetrical fault current, ANSI X/R ratio, and multiplying factor.

IEC-60909 is the European counterpart, which is derived from German VDE Standard (Kaloudas et al., 2010; Rodolakis, 1993). It is concerned ultimately with protective devices sizing, but mainly with fault current calculation.

Some of SC calculation algorithms are embedded in PSS®E module to meet various requirements of fault studies such as ASCC, IEC, and ANSI. These algorithms require a convergent power flow and for the simulation of unsymmetrical faults, sequence data of the system should be provided.

Using PSS/E in proper sequence could handle various investigations for planning studies and operating analyses of electric power system (Habbi & Alhamadani, 2018). As PSS/E represents an effective module and user pleasant tool to implement power system analyzes, it was chosen for simulating Nassiriya power plant with auto transformers 400/132 KV in this paper as it represents part of south region of Iraqi electrical power system (Lafta, Shalash, Abd, & Al- Lami, 2018).

When system evaluation process is to be established especially for system planned expansion, there is a need to adjust grid protection by using the appropriate method that calculates SC current with high accuracy; affecting protective devices ratings; to judge the “propriety” of system final configuration (Gallucci, 2018).

Most researches that use PSS®E to calculate SC current they apply ASCC algorithm, which is embedded as a default PSS®E SC current method of calculation (Choi, Park, Cho, & Lee, 2019; Ding, Ge, Cao, Qi, & Yang, 2011). However, IEC and ANSI had approved standard calculation of SC capability for protective devices.

Our paper introduces an important comparative study between these three methods; by developing faults which are fast and has high convergence (Jahanirad & Karam, 2017); and which of them is to be used by the Ministry of electricity in Iraq for future plan studies.

This paper is structured as follows; Section 2 describes in general fault analysis in power systems. Section 3 demonstrates IEC 60909 standard, while ANSI standard is demonstrated in Section 4. Automatic sequence calculation—ASCC—is described in Section 5. Section 6 is comparing ASCC with standards in PSS/E application. The case study is in Section 7, and the obtained results in Section 8 which is concluded in Section 9.

2. Fault analysis (Ahmedi & Azhari, 2018; Das, 2012; De Metz-Noblat, Dumas, & Poulain., 2005; Najafi, Ebrahimi, Babaei, & Hoseynpoor, 2011; Schlabbach, 2008; Thurner & Braun, 2018)

Electric power grids are designed in such way to limit SC current to avoid melting, burning or may be explosion of grid components. Equipment characteristics are determined in such a way to interrupt or withstand the calculated SC current; at every level of installation (de Metz-noblat et al., 2005; Thurner & Braun, 2018).

AC fault current is named steady state or symmetrical fault current which is calculated using Equation (1).

$$i_{ac}(t) = \frac{\sqrt{2}V}{Z} \sin(\omega t) \quad (1)$$

Where V is the RMS voltage, Z represents circuit impedance that forms suitable output currents (Ahmedi & Azhari, 2018).

Aperiodic or Dc fault current is considered in Equation (2).

$$i_{dc}(t) = -\frac{\sqrt{2}V}{Z} \sin(\alpha - \theta) e^{-t/T} \quad (2)$$

Where α is switching angle, and T is the reactance to resistance ratio.

$$T = \frac{X}{R}$$

Total SC current, asymmetrical fault current, is the sum of ac symmetrical component and aperiodic component as in Equation (3).

$$i(t) = i_{ac}(t) + i_{dc}(t) \quad (3)$$

The corresponding root mean square value is:

$$I_{RMS} = \sqrt{I_{ac}^2 + I_{dc}^2}$$

$$I_{RMS} = \sqrt{I_{ac}^2 + 2I_{ac}^2 e^{-t/T}} \quad (4)$$

The mathematic equation relates the asymmetrical component to the symmetrical one is:

$$I_{asym} = I_{sym} \sqrt{1 + 2e^{-2\pi/(X/R)}} \quad (5)$$

Sequence voltages are:

$$\begin{bmatrix} V_0^A \\ V_1^A \\ V_2^A \end{bmatrix} = \begin{bmatrix} 0 \\ V_{Fpu}^A \\ 0 \end{bmatrix} - \begin{bmatrix} Z_0 & 0 & 0 \\ 0 & Z_1 & 0 \\ 0 & 0 & Z_2 \end{bmatrix} \begin{bmatrix} I_0^A \\ I_1^A \\ I_2^A \end{bmatrix} \quad (6)$$

Adding the three rows of Equation (6) yields Equation (7) for 3 phase fault:

$$V_0^{Bus} + V_1^{Bus} + V_2^{Bus} = V_F^{BusA} = V_{Pu}^A - I_1^A Z_1 \quad (7)$$

But:

$$I_F^{BusA} = \frac{V_F^{BusA}}{Z_f}$$

Then:

$$I_F^{BusA} Z_f = V_F - I_1^A Z_1 \quad (8)$$

Figure 1 shows balanced three phase (3-PH) fault which represents severe type of fault and probability of occurrence is minimum (Najafi et al., 2011) that is solved as:

$$I_F^{Bus} = \frac{V_F^{Pu}}{Z_1 + Z_f} \quad (9)$$

Where the system voltages of symmetrical components are:

$$V_{012}^{FBus} = V_{012}^{BusPu} - Z_{012}^{Bus} I_{F012}^{Bus} \quad (10)$$

Solving Equation (7) for line to ground (L-G) faults assume phase A is faulty:

$$V_F^{BusA} = V_{Pu}^A - (Z_0 + Z_1 + Z_2) I_0^A \text{ as } (I_0^A = I_1^A = I_2^A)$$

Then

$$I_F^{BusA} = \frac{3V^{BusA}}{Z_0 + Z_1 + Z_2 + 3Z_f} \quad (11)$$

It is clear that the ratio X/R for line-to ground fault is:

$$(X_0 + X_1 + X_2)/(R_0 + R_1 + R_2) \quad (12)$$

Transient conditions develop SC current I_{sc} , depending on SC impedance Z_{sc} :

$$Z_{sc} = \sqrt{R^2 + X^2}$$

To calculate SC current, the sequence illustrated in Figure 2 is followed.

The earliest prospect of saved power flow must incorporate fault analysis data for all sequences to be handled together. This step minimizes error caused by mistaken fault analysis data update through matching data changes.

Solving power flow pre switching system provides the base for initiating conversion of generators and loads as constant admittance.

Figure 1. Three phase balanced fault.

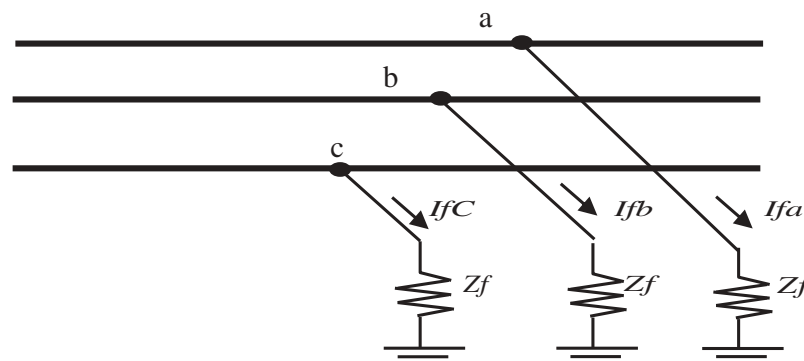
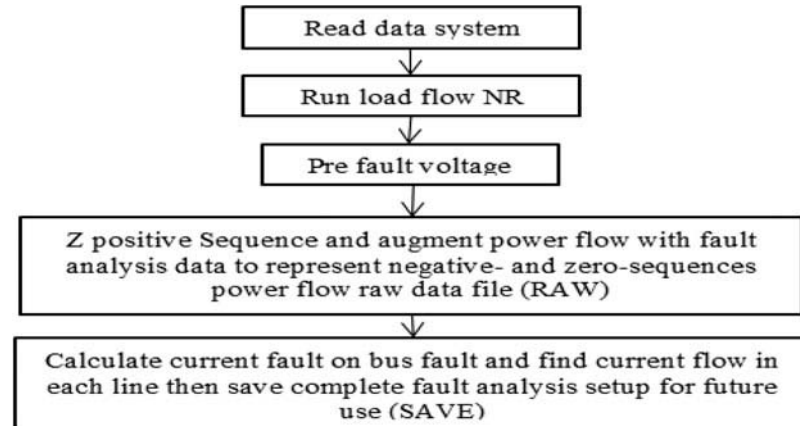


Figure 2. Sequence of SC current calculation in PSS/E.



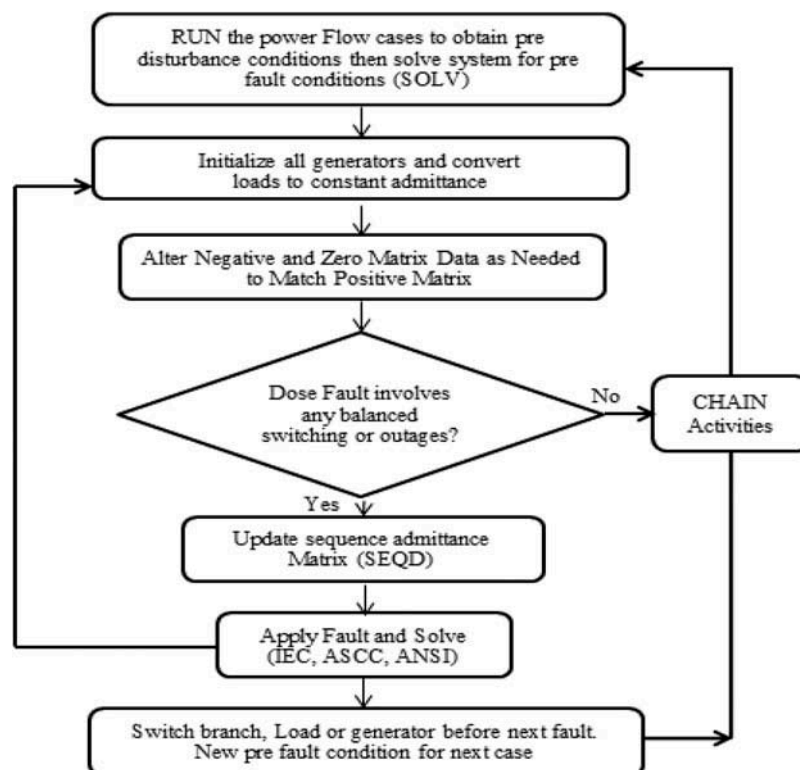
The research methodology to study and comparing the results to judge which is suitable to use in developing Iraq power system is clarified at the flow chart shown in Figure 3.

3. IEC 60909 (Berizzi, Massucco, Silvestri, & Zaninelli, 1994; Das, 2012; De Metz-Noblat et al., 2005; International Standard Iec, 2016; Nedic, Bathurst, & Heath, 2007; Schlabbach, 2008; Sweeting, 2012)

For low, medium, and high voltage, 3-PH ac systems with frequency of (50 or 60) Hz; this standard is applicable for SC calculation.

Initial symmetrical SC current I_k is the rms SC current of the ac symmetrical component at the instant of the SC because a defined value is required and the ac component may decay for faults near the generator, while I_{dc} is the decayed component of SC current.

Figure 3. Procedure of finding SC current by the three methods IEC, ASCC, and ANSI in PSS/E.



The same X/R ratio is useful to calculate dc SC component I_{dc} as in Equation (13):

$$I_{dc} = \sqrt{2}I_k'' * e^{-2\pi f \cdot t \cdot b \cdot R/X} \quad (13)$$

Where I_k'' is the symmetrical SC current, f is the frequency, t is time.

The maximum instantaneous, peak, SC current is I_p , which depends on X/R value and phase angle; $R/X \approx \cos\phi$; at fault starting can be calculated using Equation (14):

$$I_p = K * \sqrt{2} * I_k'' \quad (14)$$

Where $K = 1.02 + 0.98e^{-3\frac{R}{X}}$

I_b is the rms value of ac symmetrical SC breaking current at contact separation' instant to open switching device which is evaluated using Equation (15):

$$I_b = \mu I_k'' \quad (15)$$

Where: μ is the minimum time of delay.

The most important differences from other SC calculation methods are the use of a voltage correction factor, as shown in Table 1, and impedance correction factors.

IEC SC current calculation activity in PSS/E version 32 needs additional data for demonstrating machines and transformers. Figure 4 shows main screen of IEC fault calculation in PSS/E with some parameters that can be selected.

4. ANSI

In PSS/E, this standard fault current calculation makes use of input data files that have fault locations, maximum operating voltages, and contact parting times; besides ignoring fault resistance.

This standard studies the original network twice: one using equivalent Thevenin resistance only and the other uses equivalent Thevenin reactance only to determine X/R at fault point which is useful for asymmetrical fault current calculation. This is achieved for subtransient and steady state SC current (IEEE, 2006; Lakshmi Sankar & Mohamed Iqbal, 2015). Correction factors of rotary machines' impedance have significant effect on SC calculation.

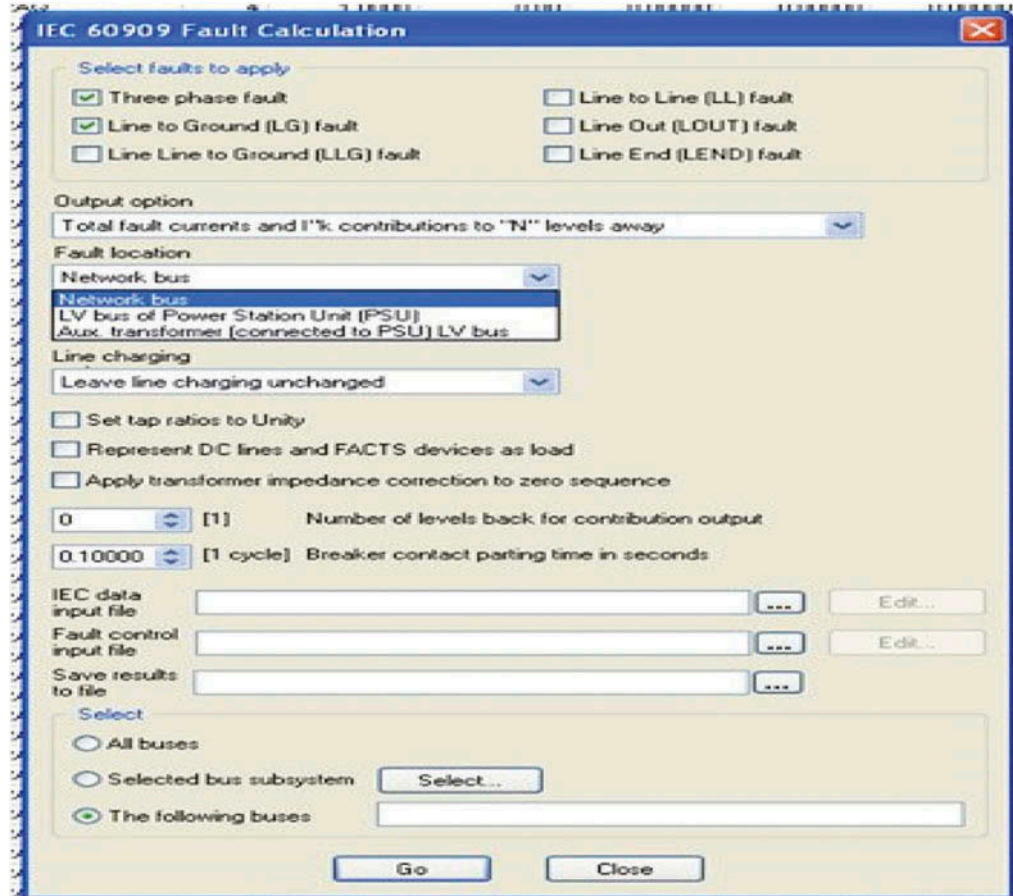
SC current is calculated using two methods (Das, 2012):

$$a. \frac{X}{R} \leq 17$$

Table 1. Voltage correction factor IEC 6038

Nominal voltage, U_n	Voltage factor c for calculation of	
	Maximum SC current	Minimum SC current
Low voltage (100–1000) V		
Tolerance +6%	1.05	0.95
Tolerance +10%	1.1	0.95
Medium voltage (1–35) KV	1.1	1
High voltage > 35KV	1.1	1

Figure 4. IEC fault calculation screen in PSS/E.



With prefault voltage V behind the transient reactance which is equal to the terminal voltage at no load; the calculated value of V/X is compared with symmetrical interrupting capability of the protective devices, as long as the circuit X/R ratio equal 17 or less, for three-phase faults. In this case, it is impossible that asymmetrical SC duty exceeds the symmetrical SC duty because the asymmetrical rating of the circuit protective devices exceeds the symmetrical capability.

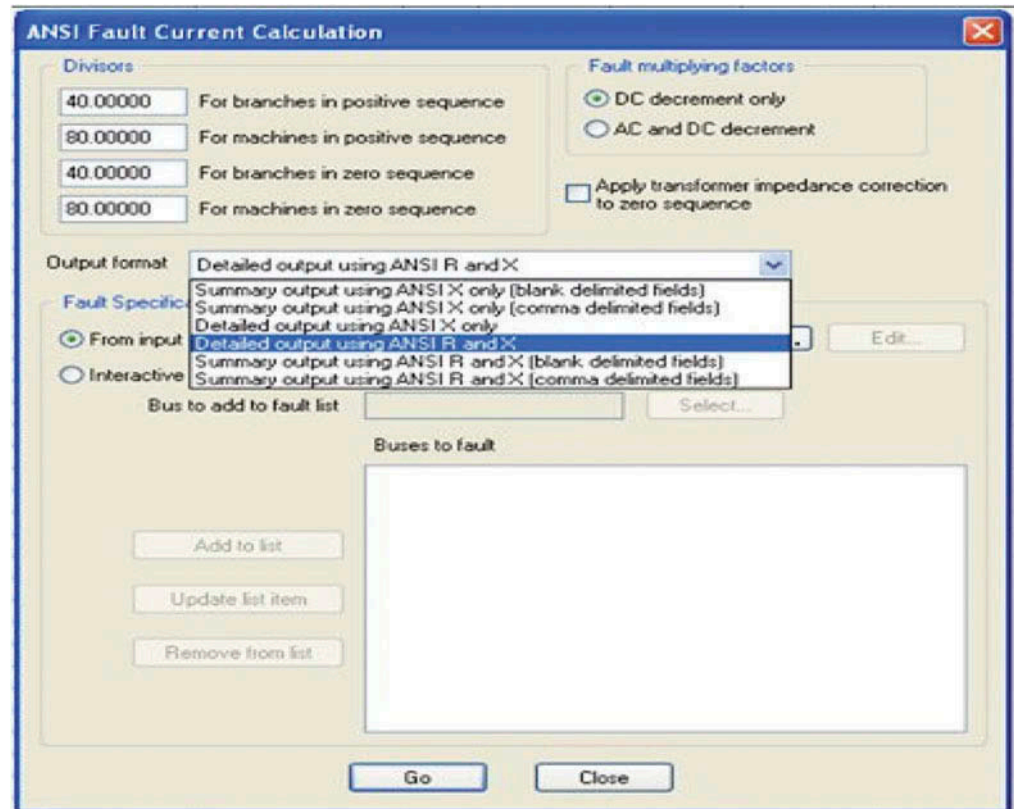
$$b. \frac{X}{R} > 17$$

SC current' dc component may increase SC duty to the extent that exceeds protective devices rating. These devices might be instantly applied without calculating resistance, X/R ratio, and fault location (remote or local) of the system as long as V/X value doesn't exceed 80% of symmetrical interrupting capability of the protective switch.

When V/X is found and X/R ratio is known, then protective devices interrupting duty could be estimated by means of multiplying the resultant SC current by a suitable multiplying factor. The multiplying factor depends on: X/R ratio, protective devices contact parting time and decaying effects of ac and dc (Das, 2012).

ANSI calculation of SC current activity in PSS/E needs the data of maximum operating voltages, fault positions, and contact parting times. ANSI main screen for fault calculation in PSS/E with some parameters that may be selected is shown in Figure 5.

Figure 5. ANSI fault calculation screen in PSS/E.



5. Automatic sequence calculation (ASCC) (PSS/E, 2015)

ASCC offers automatic standard events coverage at all buses contained in a section of the system. Only three-phase and line-to-ground SC can be handled by ASCC. Line-connected shunt devices and charging capacitance can be included in the system model. Apparent impedance at each branch is calculated as follows:

$$Z_{seq} = v_{seq}/i_{seq}, Z_{phase} = v_{phase}/i_{phase}$$

Where i_{seq} , i_{phase} represent current flowing through branch that include line-charging current and current of line-connected devices.

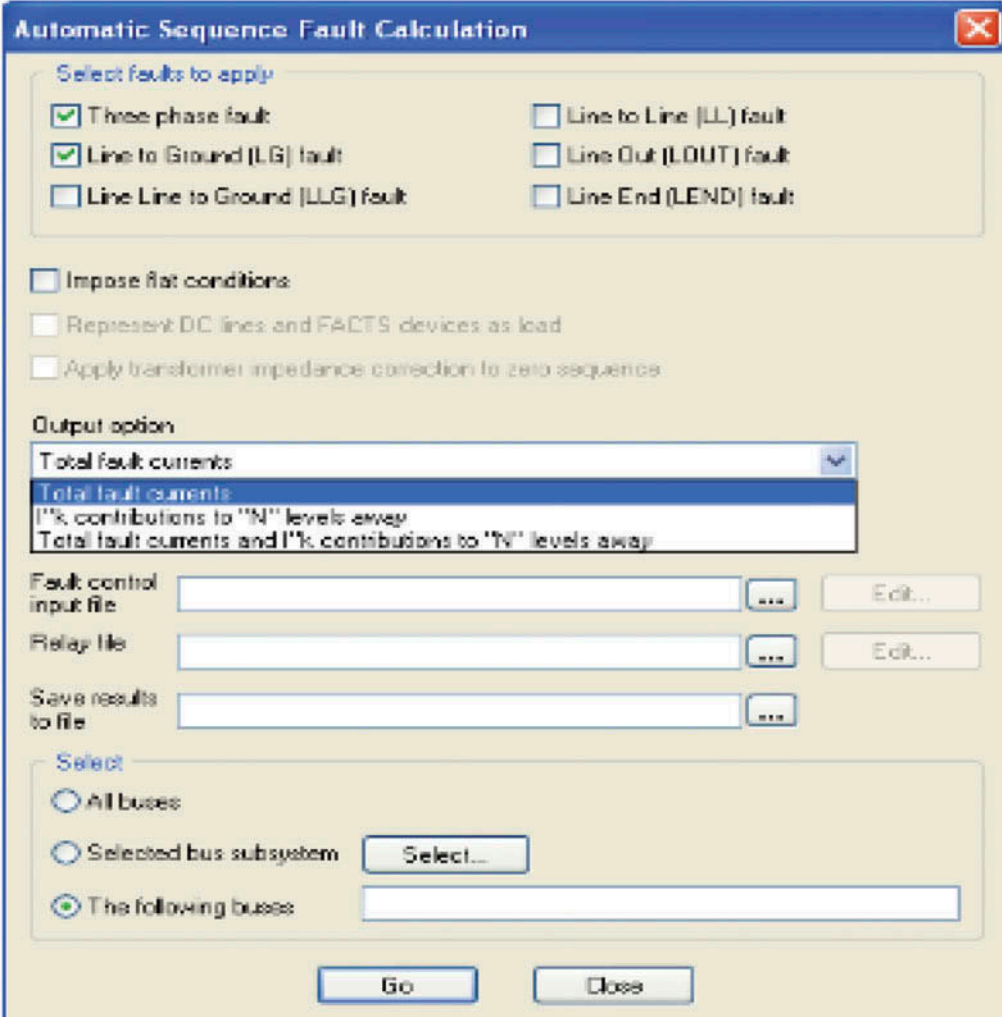
The reciprocal of apparent impedances represents apparent admittances.

ASCC uses existent full working case detail, and generator internal sources' setup is handled automatically to harmonize conditions just before disturbance application. Mutual and phase self-impedances of each branch are assumed to be balanced when ASCC is applied.

If FLAT option of ASCC is chosen; then data of working case is ignored, all bus voltages are set to $(1 + j0)$, all generator outputs; (PGEN + jQGEN); are set to zero and all phase-shift angles of transformer is to be zero. Beside setting all loads to zero, load current before and after event solution, is ignored.

Data need is specified according to various fault and report options in SC calculation activities in ASCC. Figure 6 illustrates main screen of ASCC fault calculation in PSS/E.

Figure 6. ASCC fault calculation screen in PSS/E.



6. Comparing ASCC with standards in PSS/E

Each method implements SC studies with PSS/E version 32; ASCC, IEC, and ANSI; requires specific input information, which may differ from one method to another beside those which may met in.

The input information that they met in some methods are shown in Table 2, and input information dissimilarities are shown in Table 3. Each method owing its output information is presented in Table 4.

7. Case study

Nassiriya power station is taken as the case study of this paper which have busbar number (25,403) of 400KV that is connected to Nassiriya (4×210 MW) power plant and (1×40 MW) on 132KV side is connected to busbar number (25,304). SC response has been studied for (L- G) fault and (3PH) fault on busbars (25,403) and (25,304). ANSI C37.5, IEC 60909 standards and ASCC are used to analyze SC response of the system.

Table 2. Input information that are common in some methods of fault calculation in PSS/E

Input information	Fault calculation methods
Set generator positive sequence reactance to synchronous or sub transient/transient.	ASCC, ANSI, and IEC
Set synchronous/asynchronous machine power outputs to $P = 0$, $Q = 0$.	
Transformer tap ratios and phase shift angles unchanged.	
Facts and Dc lines are blocked.	
Impedance corrections to transformer zero sequence impedances are applied.	
Set pre-fault voltage on all buses to one Pu at zero phase shift angle.	ASCC & ANSI
Line charging represented in \pm & zero sequences set to zero.	
Line/fixed/switched shunts and transformer magnetizing admittance represented in \pm & zero sequences set to zero.	
Load represented in \pm & zero sequences set to zero.	ASCC & IEC
Set induction machine positive sequence reactance to subtransient.	

Table 3. Input information dissimilarities in fault calculation methods in PSS/E

Input information	Fault calculation methods
Constant power, current, and admittance loads are neglected in positive and negative sequence networks. Grounded loads are represented in zero sequence networks.	ASCC
Transformer phase shift angles are assumed to be zero. Any transformer impedance, which is a function of phase shift angle, is assumed to be at nominal value.	
Transformer turns ratios are assumed to be one.	
Voltage factor $c = 1.05$ for bus base ≤ 1 KV and $c = 1.1$ for bus base > 1 KV.	IEC
Zero Sequence Mutual Impedances and Grounding Impedances with $R = 0$ Not Scaled Using SScaling Factors.	
Set transformer magnetizing admittance = 0 and Line/Fixed/Switched shunts = 0 in \pm Sequences.	ANSI
Zero Sequence Mutual Coupling Unchanged.	
Contact parting times, in seconds = 0.033.	
For machines in positive and zero sequence network = 80.	
For branches in positive and zero sequence network = 40.	
Protective switches are rated on a total current basis.	
Output Format = Summary output using ANSI R and X or consider X Only.	
Account for both Ac and Dc decrements (Fault multiplying factors).	

Figure 7 shows pwer flow in Nassiriya power plant interconnected to other buses.

8. Results

It is obvious from previous sections that ASCC doesn't deal with DC components thus asymmetrical current is not calculated in this method.

For Nassiriya power plant as part of 400 KV, grid is examined with 3-PH and single L-G fault occurrence. SC current results, X/R ratios and factors associated with standards and ASCC is shown in Table 5 and the results is clarified in Figure 8, which illustrates that the maximum X/R and factor values was used by ANSI for L-G fault while the maximum asymmetrical current occurs during ANSI appliance in case of 3-PH fault.

Table 4. Output information dissimilarities in fault calculation methods in PSS/E

Output information	Fault calculation methods
Instantaneous SC current are calculated for a series of faults with and without including initial system conditions	ASCC
For Line End (LEND) fault cases, in addition to selection of fault to display and display quantity, specify the branch connected to faulted bus whose far end (from faulted bus) is being faulted.	
For Line Out (LOUT) fault cases, in addition to selection of fault to display and display quantity, specify the branch or three winding transformer that is intentionally outage.	
Contour diagram of maximum fault current at each faulted bus considered.	
Total fault current and fault current contributions at home bus.	
Total fault current for all faulted buses and for all fault types considered.	IEC
Initial symmetrical SC current I ^{"k} in (r.m.s) including phase and sequence.	
components of fault current: ip(B) Peak SC current using method B of IEC standard 60909. ip(C) Peak SC current using method C of IEC standard 60909. ib(DC) DC component of asymmetrical breaking current using method C R/X ratio. ib(ASYM) Asymmetrical breaking current (r.m.s.). ib(SYM) Symmetrical breaking current (r.m.s.).	
L-G fault results: symmetrical fault current (kA), asymmetrical fault current (kA), multiplying factor, and the ANSI X/R ratio.	
L-L-G fault results: symmetrical phase current (kA), and three times the zero sequence symmetrical fault current (kA).	
The positive sequence Thevenin impedance as obtained from the decoupled positive sequence admittance matrices.	ANSI
The bus number, name and base voltage of the faulted bus, along with the maximum operating voltage and contact parting time input values.	

Figure 7. Nassiriya power plant power flow diagram.

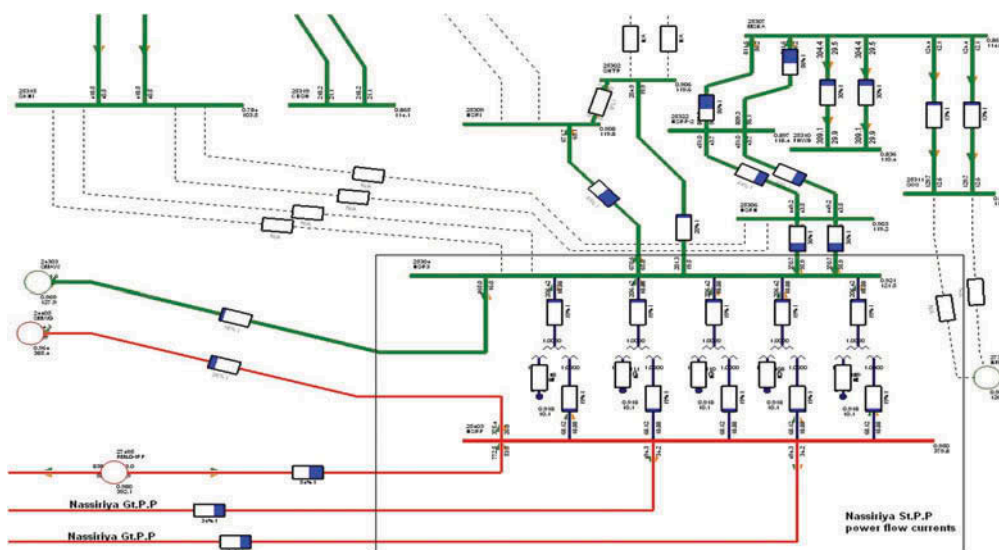
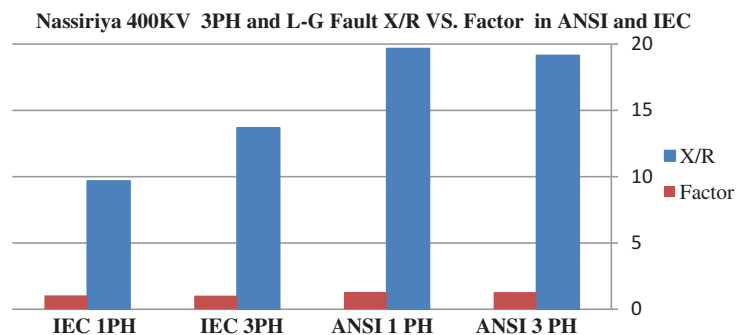


Table 5. SC current, X/R and factors of faulted Nassiriya 400 KV in ANSI, IEC standards & ASCC

Standards	Fault type	X/R Ratio	Symmetrical current (KA)	Asymmetrical current (KA)	Factor
ANSI	3-ph	19.14	26.396	34.189	1.295
ANSI	L-G	19.66	25.271	33.001	1.306
IEC	3-ph	13.68784	26.7582	27.4298	1.025
IEC	L-G	9.6809	26.4737	27.6783	1.046
ASCC	3-ph	6.7492	24.5886	-	-
ASCC	L-G	-	23.073	-	-

Figure 8. X/R and factors of faulted Nassiriya 400 KV in ANSI and IEC.



For Nassiriya, as part of 132 KV grid, Table 6 shows SC current results, X/R ratios and factors associated with standards and ASCC; corresponding to 3-PH and single L-G fault on Nassiriya 132 KV and results are clarified in Figure 9 which illustrates that the maximum X/R, highest factor, and maximum asymmetrical current occurs during the use of ANSI method.

The following types of faults are examined on Nassiriya 400 KV and 132 KV. SC current and X/R ratio of the connected buses to the faulted bus in ANSI, IEC, and ASCC are shown as below:

- (1) **Three phase fault in Nassiriya 400 KV:** results are listed in Table 7 and cleared in Figure 10 showing that the highest X/R value is within the use of both standards ANSI and IEC at Nassiriya busbar while during the application of ASCC, X/R high value is at Simawa busbar. The ultimate SC current value is also at Nassiriya busbar using IEC standard.
- (2) **Line to ground fault on Nassiriya 400 KV:** results in Table 8 and clarified in Figure 11 showing that IEC SC current value is the highest at Nassiriya busbar.

Table 6. SC current, X/R and factors of faulted Nassiriya 132 KV in ANSI, IEC standards and ASCC

Standards	Fault type	X/R ratio	Symmetrical current (KA)	Asymmetrical current (KA)	Factor
ANSI	3ph	20.05	32.773	43.048	1.313
ANSI	1ph	21.03	37.879	50.110	1.323
IEC	3ph	15.2081	32.4141	33.6426	1.038
IEC	1ph	16.8748	39.2187	41.2597	1.052
ASCC	3ph	6.8365	29.4114	-	-
ASCC	1ph	-	33.590	-	-

Figure 9. X/R and factors of faulted Nassiriya 132 KV in ANSI and IEC.

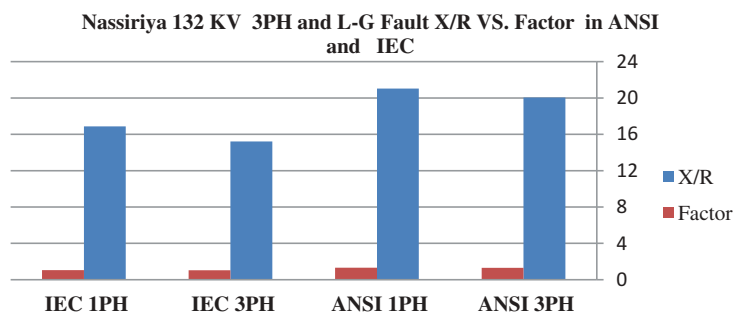


Table 7. SC current and X/R results in ANSI, IEC, and ASCC for 3- PH fault on Nassiriya 400 KV

Bus number and name	ANSI Standard		IEC Standard		ASCC	
	I_{SC} (A)	X/R ratio	I_{SC} (A)	X/R ratio	I_{SC} (A)	X/R ratio
25403 NSRP	26395.8	19.14	27274.6	13.688	24588.6	6.7492
24405 SMWG	3109.0	9.091	3173.6	9.091	2956.9	9.037
25412 NSRG	6257.9	8.13	6299.4	8.13	5727.9	8.13
27495 RMLG	3698.4	9.027	4065.6	9.027	3560.6	8.894

Figure 10. Buses SC current and X/R in ANSI, IEC and ASCC; for three-phase fault on Nassiriya 400 KV.

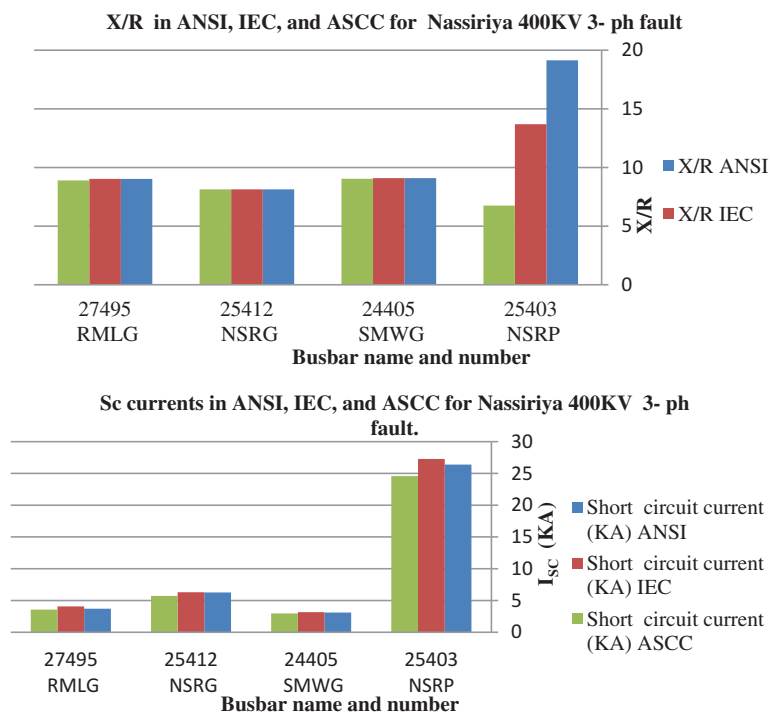
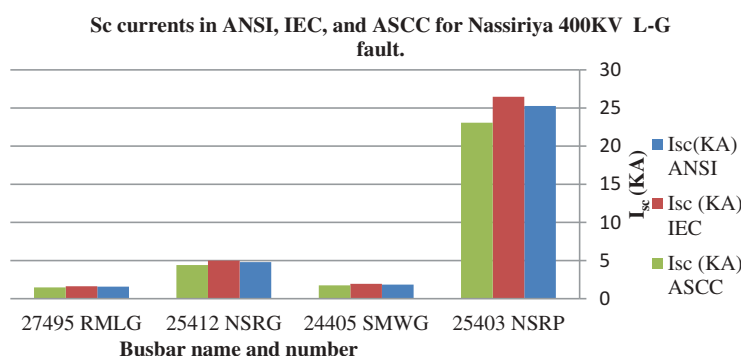


Table 8. SC current and X/R ratios in ANSI, IEC, and ASCC for L-G fault on Nassiriya 400 KV

Bus number and name	NSI Standard		IEC Standard		ASCC	
	I_{sc} (A)	X/R ratio	I_{sc} (A)	X/R ratio	I_{sc} (A)	X/R ratio
25403 NSRP	25271	19.66	26473.7	9.681	23073	
24405 SMWG	1852.7	3.994	1940.1	11.078	1752.6	10.806
25412 NSRG	4788.6	6.093	4997.7	5.354	4412.9	5.308
27495 RMLG	1580.1	3.923	1628.1	20.413	1483	19.464

Figure 11. Buses SC current in ANSI, IEC and ASCC for L-G.



8.1. Fault on Nassiriya 400 KV

- (3) **Three phase fault on Nassiriya 132 KV:** the ultimate SC current value is by IEC usage as illustrated in Table 9 and Figure 12.
- (4) **Line to ground fault on Nassiriya 132 KV:** also results ensure that IEC is the highest SC value at Nassiriya busbar as shown in Table 10 and Figure 13.

Table 9. SC current and X/R ratios in ANSI, IEC, and ASCC for three phase fault on Nassiriya 132 KV

Bus number and name	ANSI standard		IEC standard		ASCC	
	I_{sc} (A)	X/R ratio	I_{sc} (A)	X/R ratio	I_{sc} (A)	X/R ratio
25304 NSRP	32773.5	20.05	33264.6	15.208	29411.4	6.8365
24303 SMAW	2243.3	6.172	2097.4	6.172	2015.4	6.139
25306 NSRN	3895.2	5.588	4176.7	5.588	3398.6	5.588

Figure 12. Buses SC current in ANSI, IEC and ASCC for Nassiriya 132 KV three-phase fault.

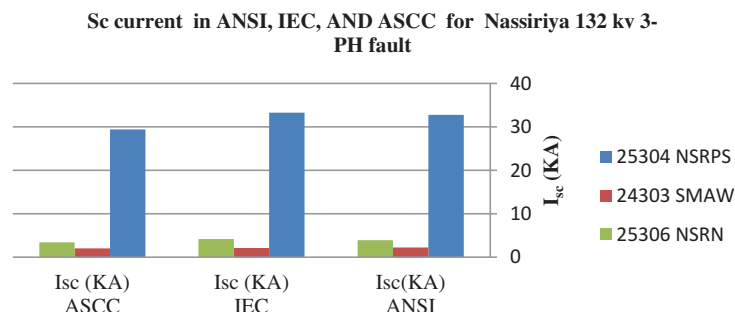
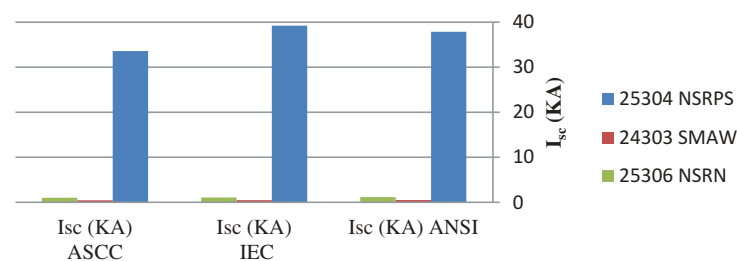


Table 10. SC current and X/R results in ANSI, IEC, and ASCC for L-G fault on Nassiriya 132 KV

Bus number and name	ANSI standard		IEC standard		ASCC	
	I_{SC} (A)	X/R ratio	I_{SC} (A)	X/R ratio	I_{SC} (A)	X/R ratio
25304 NSRP	37878.7	21.03	39218.7	16.875	33590	
24303 SMAW	497	4.665	464.7	13.169	447.4	12.872
25306 NSRN	1162.2	3.939	1064.5	7.962	1017.1	7.930

Figure 13. Buses SC current in ANSI, IEC, and ASCC for Nassiriya 132 KV L-G fault.

Sc current in ANSI, IEC, AND ASCC for Nassiriya 132KV L- G fault



As pointed out in the introduction that there are several programs which calculate the SC by both the ANSI and IEC standards. Lakshmi Sankar and Mohamed Iqbal (2015) reviewed the study of these standards by ETAP for thermal power station by testing the system at different locations such as bus network and bus generator.

It is important to compare Sankar and Iqbal results with the obtained PSS/E results for symmetrical and asymmetrical Fault; Single line to ground and for both the IEC and ANSI standards.

Table 11 shows the SC results of the IEC and ANSI standards by PSS/E for the same system and their results by ETAP in Lakshmi Sankar and Mohamed Iqbal (2015). Comparison results represent a convergent benchmark.

Table 11. Results of the IEC and ANSI standards by PSS/E and ETAP results for symmetrical and unsymmetrical Fault

Type of standard Type of Fault	IEC 60909 standard PSS/E (KA)	ANSI PSS/E (KA)	IEC 60909 standard ETAP (KA)	ANSI ETAP (KA)
Symmetrical Fault Occurs At Grid Bus	50.09	49.739	50.15	49.994
Symmetrical Fault Occurs At Gen Bus	79.654	75.651	81.634	74.391
Unsymmetrical Fault Occurs At Grid Bus	52.949	52.949	53.667	53.45
Unsymmetrical Fault Occurs At Gen Bus	0.21	0.2	0.22	0.2

9. Conclusion

Paper results are obtained by using ANSI, IEC 60909 standards and ASCC using PSS/E version 32. Standards give methods to calculate symmetrical steady state current that is multiplied by a factor for the purpose of finding the peak value of asymmetrical current; ANSI output gives the value of that factor while it was a hand calculation in IEC in Tables 5 and 6. Giving that ASCC doesn't deal with dc current; thus asymmetrical current is not calculated in that method and also the factor. In L-G fault, X/R of Nassiriya 400 KV and 132 KV buses is not given by IEC method and was a hand calculation in Tables 8 and 10, respectively.

ANSI adjusts machine reactance using a multiplier; these multipliers don't take into account fault position and break parting time, while IEC recommends including parting time and making machine proximity to SC.

However, ASCC and ANSI are accepted methods for SC calculation. But when studies for the grid expansion are held, it is important to use IEC fault current calculation for its high accuracy resulting in a protected grid, as the instantaneous SC current are used for determining breaking capacity.

Funding

The authors received no direct funding for this research.

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Citation information

Cite this article as: IEC 60909 and ANSI standards comparison with ASCC based fault calculations of Iraqi power system, Yasar N. Lafta, Nadheer A. Shalash, Yaser N. Abd & Ali A. Al- Lami, *Cogent Engineering* (2019), 6: 1705654.

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