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Challenges of Fault Current Analysis using IEC 60909 and ENA G74 in Grids Dominated by Converter Fed Generation

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***Abstract*—Fault current analysis is a key part of designing, managing and analysing an electrical network. The traditional IEC 60909 calculation method has been well established in standards for many decades, however it is based on a number of simplified assumptions to make the computational process simple and efficient. A comparison is also included with the ENA G74 short circuit calculation method. The assumptions used in these methods are creating misleading results in large renewable energy generation plants that have a significant portion of Converter Fed Generation (CFG), by overstating the retained voltages and increasing the calculated fault levels. This paper shows how these assumptions break down in generation sites dominated by CFG, and can produce unrealistic results, due to the constant current output of the CFG. The paper also outlines some of the shortfalls in assessment of Grid Forming Inverters fault contribution.**

***Keywords*— ENA G74, Fault Current Analysis, Grid Following Inverter, Grid Forming Inverter and IEC 60909.**

I. Introduction

A. Introduction

Fault current analysis is a key formal analysis process carried out in the design of new and existing power systems. The traditional IEC 60909 calculation method [1] has been well established in standards for many decades, and is recognized as not fully considering Converter Fed Generation (CFG). The more recent UK based ENA G74 standard [2], has some methods to address the issue of increased presence of CFG, but still does not address some of the underlying problems with the methodology. As well as being used for analysis of fault levels for selection of switchgear ratings, it has also been noted that short circuit calculations are often also used as a measure of system strength, with the Short Circuit Ratio (SCR) being derived from an IEC 60909 / ENA G74 fault study. SCR is commonly used as a metric for assessing suitability for connections, and use of these calculation methods may give misleading results [2], [3] & [5].

Modern networks contain significant percentages of CFG that are based on Grid Following Inverter (GFL) technology, and are increasingly also including Grid Forming Inverters (GFM). This paper demonstrates how the use of traditional IEC 60909 and ENA G74 calculation techniques can give misleading results, and shows that for modern power systems, the standard must be updated.

The IEC standard was last updated in 2016, and uses a number of simplified assumptions to make the computational process simple and efficient. The standard notes that it is based on the assumption that any CFG is a small percentage of the overall system. Furthermore, it treats CFG as a simple current source, and does not address the behavior of GFM technology. The ENA G74 standard is more recent, and was updated in 2020, and began to address some of the shortfalls in the IEC method, but is not widely used outside of the U.K., however it is implemented as the 'complete' method within DigSILENT Powerfactory. The IEC 60909 standard is currently undergoing review and has a planned publication date in 2026. In the interim caution must be used when utilizing the IEC method in large CFG dominated networks.

A simple test network is used for illustrative purposes within the paper to demonstrate how CFG based plants can displace the retained voltage during a fault to unrealistic values, and how networks with low grid infeed fault levels can result in unrealistic fault values on switchboards. Planned further work is to expand the analysis to larger meshed networks, with more complex impedance paths, and to validate the analysis with time-based simulations.

B. Contributions to Knowledge

A number of research papers have acknowledged the shortfall within IEC 60909 for CFG contribution [5], [6] & [7], whilst further research has also indicated how the use of simplified fault level calculations may over-estimate system strength [8]. This paper demonstrates how traditional IEC 60909 and ENA G74 based fault level analysis calculations can over-estimate the fault level, as the treatment of CFG as simple constant current sources impact the retained voltage; and does not consider that the fault contribution from the CFG is managed by the control logic, and only occurs in specific conditions. Modified equations are provided to suggest consideration of the fault current contribution for GFL technology are provided, and some suggestions on modelling GFM inverters.

II. Fault Calculation Methodology

A. Standards

Fault level calculations are traditionally performed with simplified formal methods such as IEC 60909 and ENA G74. These methods are simple, robust and widely used to determine maximum fault levels and system strength and use a range of simplifications to determine the system impedance and fault contribution from generators to determine the fault levels. These simplifications allow the process to be carried out in a fast and computationally efficient method, but are all based on the underlying principle that CFG contribution is small in comparison to the overall network contribution, is delivered instantaneously.

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B. General Method

The general method within both the IEC 60909 and ENA G74 approach is to reduce a network down to a series of equivalent impedances and sources, to a single Thevenin equivalent. These are then calculated for the relevant busbar to determine the fault parameters of initial short circuit current I"k, peak fault current, break fault current Ib, network X/R ratio and DC time constant. No time based analysis is carried out, and the time related aspects such as DC component and break current are extrapolated formulaically.

A detailed comparison between the IEC 60909 and ENA G74 methods is beyond the scope of this paper, but the principle differences are that ENA G74 uses a pre-fault loadflow as a starting position, this is a key factor as the IEC 60909 method assumes a fixed nominal bus-voltage and applies a 'c' factor to the voltage, whilst in ENA G74, a pre-fault load flow study is carried out to determine the system voltages. ENA G74 has more detailed representation of some key plant such as GFL inverters and HVDC stations and how lumped load is considered.

The general form of the equations used in the standards are shown below, in simplified format, in Equation (1) for the IEC 60909 method and Equation (2) for the ENA G74 method. In both methods an equivalent network impedance is calculated, through a series of reductions based on the characteristics of the feeders, cables, transformers etc. and reduced to an overall equivalent impedance in front of an ideal voltage source. A number of more complex adjustments and calculations are applied for calculating X/R ratio, break currents and so on, but these are not directly relevant to this paper, and therefore not discussed further.

$$I"_k = c.\frac{U_n}{Z_{th}} \tag{1}$$

$$I_{ki} = \frac{u_i}{Z_{ii}} \tag{2}$$

Lastly, it should be noted that most simulation programs appear to calculate the fault level of all busbars simultaneously, however this is not actually what happens, within the simulation package. Instead, the software calculates the fault level at each busbar sequentially and then compiles all the results into a single set of data. Thus when running an overall fault study, individual odd behaviour may not always be visible.

C. Grid Following Inverter Response

A Grid Following Inverter (GFL) is often considered as a constant current source, with a nominal maximum fault contribution as a ratio of between 1.1-1.5 of I_N. The inverter response can only be sustained for a number of cycles, until the IBR current limit logic restrains the output. Furthermore, the magnitude of the fault contribution of the GFL is set by the Fault Ride Through (FRT) control logic of the inverter, which is triggered in specific circumstances, usually when the system voltage falls below a certain threshold.

Some development associations, such as ENTSO-E and the European Union Requirements for Generators (RfG) [9] have detailed specific requirements, and the Western Electricity Coordinating Council (WECC), and have produced generic models, defining such parameter, where the fault contribution trigger threshold, is referred to as V_{dip}, [5], but the exact nomenclature varies between equipment manufacturers. It should be noted that the actual GFL fault output exhibits complex behaviour during real system faults, as the fault output is defined primarily by the control systems, and has a limited and time-delayed response, and so the IEC and ENA methods must necessarily contain simplifications.

Within the G74 standard, the fault contribution is defined as a constant current, based on the K factor of the control system, Δu is the magnitude of the voltage dip. For small signal disturbances, the FRT module of the GFL will not be triggered, as the voltage disturbance is of insufficient magnitude. The fault output of a CFG is not fully defined within IEC 60909, and stated as only a constant current source. Within the ENA G74 the fault output is modelled as current-voltage relationship defined by Equations (1) & (2).

$$\Delta I_{CDP} = K_j \Delta u_j \tag{3}$$

: if ΔI is below the maximum current

$$\Delta I_{CDPj} = I_{maxj} \tag{4}$$

:otherwise

D. Grid Forming Inverter Response

GFM based resources are more complex than GFL technology, and there are less established and confirmed control methods in operation. A number of bodies have started to define outline performance requirements for GFM technology during faults and small disturbances [19] & [20], but these are not fully established, and are not widely proven at grid scale. The output of a GFM is considered as a voltage behind an internal impedance, instead of a constant current source, and with a nominal maximum fault contribution as a ratio of between 1.5-2.0 of I_N.

In a similar manner to GFL, the output of the GFM to system disturbances is set and determined by the control logic. However, GFM based generation can provide operation in voltage-source control mode, and attempts to provide a synthetic response to a traditional synchronous machine where the GFM is able to provide some level of support for system voltage disturbances [19] & [20].

As GFM technology is still considered to be in relatively early stages, the control strategies and performances for behaviour during faults and small system disturbances vary between developers, and depends on the control strategies adopted. Some caution is therefore necessary, in defining the GFM technology fault contribution.

DigSILENT PowerFactory have taken the step of modelling a GFM inverter with the equivalent equations as shown below in Equation 5 & 46 [10].

$$|Z_1| = c.\frac{{U_N}^2}{S_k^"} \tag{5}$$

$$\frac{R}{X} = R/X^" \tag{6}$$

It should be noted that one of the fundamental differences between a GFM and a synchronous machine is that the latter inherently has a high X/R ratio with an instantaneous and decaying fault contribution, whilst a GFM will typically produce only sinusoidal fault current in response to a control

sugnal. It has been mentioned, anecdotally, from vendor data that this can create a problem in properly modelling a GFM fault contribution, as the either the initial symmetrical component *I"k* or the peak current *ip* can be modelled correctly, but not both. Proposed compromises have included setting a nominal X/R ratio of 1, but this is not an ideal solution and it is possible to align the GFM with either the peak fault current or steady state values, but not both.

Overall whilst a GFM inverter is similar to an equivalent synchronous machine, it is not truly identical and some differences are present. However, it is important to recognise that GFM and GFL have very different fault contribution capabilities that are specific to each technology. Furthermore, it is noted that some vendors have the ability to change the operating mode of a CFG between GFL and GFM, so a network may exhibit both types of output.

III. Interaction of Large Volumes of CFG

A. Consideration of GFL Constant Current Source

As noted earlier, the IEC 60909 standard does not include any specific consideration of fault contribution from GFL, however it is addressed within the ENA G74 standard. Section 6.1.2 of the standard specifically notes that the CFG injects post-fault current, as a form of controlled current source. ENA G74 uses Equations (7) & (8) to define the fault contribution from CFG plant..

The approach adopted within ENA G74 assumes that the retained voltages on the network (i.e. the voltages on the non-faulted busses), are defined by the rotating plant on the network, that is the synchronous generators, or grid source. Asynchronous machines also play a role, but are not typically present in large CFG renewable plants, and their impact elsewhere on the Grid are represented by the Grid infeed fault level. A key assumption within the standard is that the impact of CFG on retained voltages is small. For a 3-phase fault the formula is shown in Equation (8).

$$I_{ki} = \frac{u_i}{Z_{ii}} + \frac{1}{Z_{ii}} \sum_j Z_{ij} \Delta I_{CDP} = I_{kRP} + I_{kCDP} \qquad (7)$$

$$I_{k3i} = \frac{1}{Z_{(1)ii}} \left(u + \sum_j Z_{(1)ij} \Delta I_{CDP} \right) \qquad (8)$$

For Equation 7: Z_{ij} is the complex impedance between nodes, ΔI_{CDPj} is the CFG post-fault current injection and I_{kRP} and I_{kCDP} are the post-fault current injections of the rotating plant and CFG plant respectively.

For Equation 8: Z_{ii} is the complex self-impedance between nodes, Z_{ij} is the complex mutual-impedance between nodes, ΔI_{CDPj} is the CFG post fault current injection and I_{k3i} is the positive sequence fault current magnitude.

It can be seen from Equations 7 & 8 that the assumption within the ENA G74 calculation is to simply add the fault contribution from the CFG plant to the overall fault current value. IEC 60909 uses a similar approach, but is less well defined and formulized.

B. Impact of CFG on Results

The assumptions within the ENA G74 are reasonable for most situations, but for renewable power plants that have a large percentage of CFG generation, such as solar (PV), Wind Turbine Generators (WTG) or Battery Energy Storage Schemes (BESS), this assumption is often not correct. Many of these sites are located in remote areas, with dedicated feeds from the host utility network. The host utility network in many cases (such as onshore wind) may be weak, and already have a low fault level, thus the fault contribution from the CFG can be significant. For large CFG plants, two specific scenarios can arise: 1) Increase of retained voltage on remote busbar nodes throughout the network; 2) Unrealistic values calculated for local busbar faults, which apparently exceed the maximum through fault capability of the transformer.

It can be seen from the above that the second issue, is actually a consequence of the first issue, but one that only occurs in specific scenarios. What happens is that during the fault the constant current contribution from the CFG displaces the retained voltage upwards on the intact busbars, leading to a bus voltage on the unfaulted in excess of the typical value of Un = 1.1pu.

Formally, this can be considered as two busbars, where Bus A represents the faulted bus, and Bus B an unfaulted busbar, with Z_{AB} as the mutual impedance between the two busbars and I_{fault} as the fault current injected into the network during the fault. The retained voltage at Bus B can therefore be approximately determined by equation (9). If a CFG injects a specific current into the network during the fault I_{INV}, with a known impedance at the inverter terminals Z_{INV}, a voltage rise will occur at the injection point, as indicated by equation (10). The overall retained voltage at the unfaulted busbar will therefore be a combination of the retained voltage from the fault and the injected current from the CFG, and can therefore be approximated by equation (11).

$$U_{B(flt)} \approx U_{B\,(preflt)} - Z_{Bus} \cdot I_{fault} \qquad (9)$$

$$\Delta U_B \approx Z_{INV} \cdot I_{INV} \qquad (10)$$

$$U_{B(flt)} \approx U_{B\,(preflt)} - Z_{Bus} \cdot I_{fault} + Z_{INV} \cdot I_{INV} \qquad (11)$$

IV. Model & Analysis

A. Model Configuration

In order to demonstrate an example of the problems encountered within the formal fault calculation methods, a test network was developed, based on a simple industrial radial network with some CFG located in close proximity. This test network is used to demonstrate the impact of CFG on calculated fault levels. The study cases and results in this section are selected to show how both the IEC and ENA standards can break down and give misleading results, by incorrectly assuming fault contribution from the CFG, which subsequently increases the network retained voltage.

The model is based on a 33 kV distribution systems, with three identical 2.5 MVA, Dyn11, Z=7.0% transformers, supplying a local 400V switchboard, interconnected via 3c185mm^2 aluminium cable, each 10 km long. A 50 MVA CFG generator is connected to the HV1 switchboard, set with a fault current contribution of 1.5pu and X/R of 1.0 and supply 50MW of active power and 0 MVAr of reactive power. The cable type and lengths were deliberately selected to show differing retained voltages on the HV systems. The grid infeed is set with a nominal X/R ratio of 10, through all studies. For IEC studies the *c* factor is assume as 1.1, and for the G74 the

pre-fault loadflow is set to give close to 1.1 at the LV3 switchboard. The test network can be seen below in Fig. 1.

Results are given from the IEC 60909 method and ENA G74 method. Some differences between the results is to be expected, due to the slightly different methodology, however the general trends can be observed.

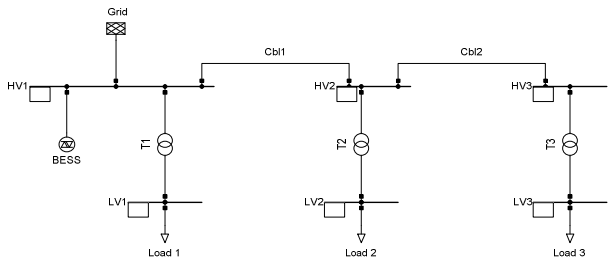


Fig. 1. Single line diagram of Test Network

B. Calculations With No CFG

A fault was applied at the LV3 busbar, to allow maximum retained voltage on the HV busbars and identify the influence of the CFG on the results. A set of initial base case simulations were carried out as a base with the CFG switched out of service, and the retained voltage on the HV busbars recorded along with the initial symmetrical fault level on LV1 busbar.

The results of the base case study with No CFG are summarised in Table I. As expected, from standard theory, as the Grid fault level decreased from 40 kA to 5 kA, the fault level on LV1 falls, and the retained voltage on the HV busbars also decreases. The results for the ENA G74 case are slightly lower than the IEC 60909 results, as the calculations use a load flow result as an initial case, rather than the fixed bus-voltage method in the IEC approach. A key observation from these results is that in all cases, apart from the ENA G74 simulation with 5 kA Grid fault level, the retained voltage on the HV1 bus exceeds 0.9pu, and thus any CFG located at this busbar would not be expected to contribute to the fault level.

TABLE I. BASE CASE RESULTS – NO CFG

Case	Grid Strength (kA)	IEC 60909		ENA G74	
		HV1 Bus Voltage (pu)	LV1 Bus Fault Level (kA)	HV1 Bus Voltage (pu)	LV1 Bus Fault Level (kA)
1	40	1.03	51.2	0.98	46.9
2	20	1.02	50.4	0.97	46.2
3	10	0.98	48.8	0.94	44.8
4	5	0.93	45.6	0.89	42.3

C. Retained Voltage Displacement

A second set of studies, were carried out with 50 MVA of CFG connected to the HV1 busbar, with the results summarised in Table II and Fig. 2. For the IEC calculation method, as predicted, the CFG provides additional support to the value of the retained voltage on the HV busbars, and for the 10 kA and 5 kA cases, show the retained voltage during the faults as >1.1pu, and the fault level on the LV1 busbar increasing, despite the Grid element fault level falling. For the ENA calculation method, the retained voltage is not supported on the HV busbars, and continues to fall as the network Grid element fault level falls.

TABLE II. CFG CONTRIBUTION CASE RESULTS

Case	Grid Strength (kA)	IEC 60909		ENA G74	
		HV1 Bus Voltage (pu)	LV1 Bus Fault Level (kA)	HV1 Bus Voltage (pu)	LV1 Bus Fault Level (kA)
1	40	1.06	52.5	0.99	47.0
2	20	1.09	53.9	0.97	46.3
3	10	**1.12**	55.5	0.96	45.9
4	5	**1.18**	58.6	0.96	46.0

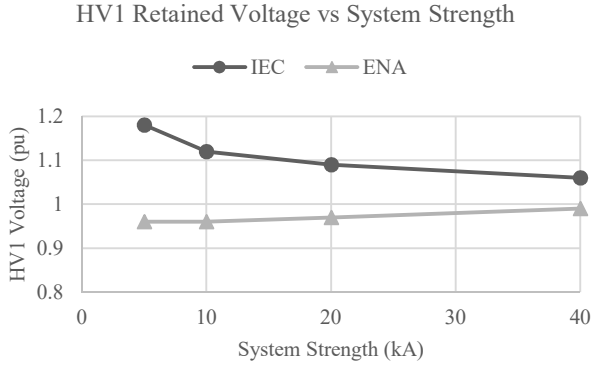


Fig. 2. Retained Voltage vs System Strength

For comparison purposes a 3rd set of simulations were carried out with the Grid fault level fixed at 10 kA, and the contribution from the CFG progressively increased from 50 MVA up to 200 MVA. As before, the results are shown for the IEC 60909 and ENA G74 case, with the results presented in Table III and Fig. 3. As with the previous case, it can be seen that in the IEC 60909 analysis method the retained voltage level rises significantly in relation to the increased penetration of the CFG plant, to a point where they are no longer credible, and the CFG, and other plant, would have tripped on overvoltage. It can also be identified that the fault level on the LV1 bus rises significantly.

TABLE III. CFG INCREASING CONTRIBUTION CASE RESULTS

Case	CFG Rating (MVA)	IEC 60909		ENA G74	
		HV1 Bus Voltage (pu)	LV1 Bus Fault Level (kA)	HV1 Bus Voltage (pu)	LV1 Bus Fault Level (kA)
1	50	**1.12**	55.5	0.96	45.9
2	100	**1.26**	62.3	0.96	45.8
3	150	**1.39**	68.9	0.97	46.4
4	200	**1.53**	75.7	0.98	46.8

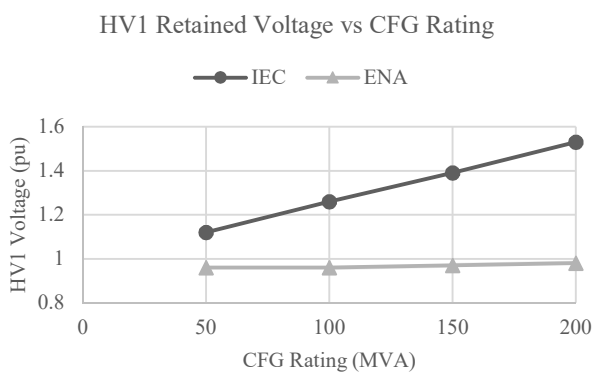


Fig. 3. Retained Voltage vs CFG Rating

D. GFM Behaviour

To define the fault contribution of GFM type inverters a set of studies are carried out, duplicating the results of Table III, but with the CFG changed to an equivalent synchronous machine, to represent a Grid Forming Inverter. As noted earlier in the paper, this model approach is not fully in line with either standard, and is based on a working assumed practice within DIgSILENT Powerfactory. As with Case III, the Grid element fault level is fixed at 10kA, and the CFG contribution is increased. The output results indicate that the retained voltages do not change to any significant level in the IEC case, as the CFG is represented as a simple equivalent impedance. In the ENA case, the retained voltages increase slightly, due to the output of the CFG.

TABLE IV. CFG EQUIVALENT SYNCHRONOUS MACHINE CASE RESULTS

Case	CFG Rating (MVA)	IEC 60909		ENA G74	
		HV1 Bus Voltage (pu)	LV1 Bus Fault Level (kA)	HV1 Bus Voltage (pu)	LV1 Bus Fault Level (kA)
1	50	0.99	49.1	0.95	45.3
2	100	1.0	49.4	0.96	45.8
3	150	1.0	49.6	0.97	46.4
4	200	1.0	49.8	0.98	46.9

E. ENA G74 – 'k' Factor Influence

In the IEC method, the fault contribution of the CFG remains fixed as a constant current output regardless of the retained voltage. The ENA G74 method considers the fault contribution of the CFG based on the retained voltage, as indicated in Equation (3). Whilst the ENA method offers a number of improvements over the IEC method, problems may arise from incorrect selection of the *k* values, and this does not fully address the issue that a GFL type inverter needs a specific voltage dip to trigger its fault contribution (typically a voltage depression of at least 0.15 pu is required to trigger the response).

To highlight the issue, a series of simulations were carried out with the Grid fault level set at 10 kA, the CFG set at 50 MVA and increasing values of *k* used. The ENA guidance indicates that the range of *k* should be between 0 and 10; however, also considered. The results of the simulation can be seen in Table V below, where as expected, the increasing value of *k* results in increased fault contribution from the CFG, which in turn increases the retained voltage on the HV1 Busbar.

The issue with the modelling approach adopted in ENA G74 is that the fault contribution of the CFG is based on an assumption that the contribution will always occur. As shown earlier, this is not the case, and the fault contribution is in fact based on a specific undervoltage trigger within the CFG.

TABLE V. G74 CFG INCREASING K FACTOR RESULTS

Case	CFG *k* Value	CFG Rating (MVA)	Fault Contribution From CFG (kA)	HV1 Bus Voltage (pu)
1	0	50	0.0	0.89
2	1	50	0.098	0.91
3	2	50	0.196	0.93
4	5	50	0.489	0.98
5	10	50	0.978	1.08

A final series of simulations are carried out with the Grid fault level set to a low value at 5 kA, the CFG set initially at 50 MVA and a fault contribution of *k*=2 and *k*=5 used, as the a typical values of *k* that would be realistically used. The rating of the CFG is progressively increased, and the fault contribution of the CFG and retained voltage examined.

The results of the simulation can be seen in Table VI and Fig. 4 below, where as expected, the increasing value of CFG presence results in increased fault contribution from the CFG and increased retained voltage on the HV1 Busbar, with a large contribution causing retained voltages that are not credible, giving rise to similar problems identified with the IEC method. Where the K factor is left as a typical lower value of 2, the issue does not become overly apparent, as the retained voltage do not become large, although the calculation method would be increasing the retained voltages beyond what would actually be expected; when the *K* factor is set to a larger value the misleading results become more notable.

The results indicate that the fundamental problem lies within Equation 3, where the injected current is a function of the difference between the nominal bus voltage and retained voltage multiplied by the *K* factor, it does not consider that a specific undervoltage is usually needed to trigger the CFG response and that the *K* factor is a simple gain.

TABLE VI. G74 CFG RISING CONTRIBUTION RESULTS

Case	CFG Rating (MVA)	K=2		K=5	
		HV1 Bus Voltage (pu)	Fault Contribution From CFG (kA)	HV1 Bus Voltage (pu)	Fault Contribution From CFG (kA)
1	50	1.02	0.22	1.08	0.542
2	100	1.06	0.44	**1.19**	1.09
3	150	1.1	0.653	**1.29**	1.629
4	200	**1.15**	0.875	**1.4**	2.714

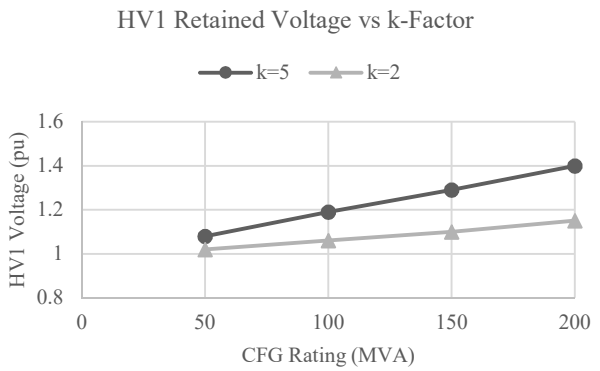


Fig. 4. Retained Voltage on Weak Grids and high k-factor

V. Refined Fault Contribution Formula

It has been shown that the base case IEC 60909 calculation method, significantly overestimates the fault contribution of any CFG within a network. The ENA G74 method, of a voltage dependent response with a gain factor *Kqv* is a reasonable approach to use within the ENA G74 calculation, method, however it does not fully capture the control response where of a CFG requires a specific voltage dip before it is triggered. In weak networks with a low fault level and high penetration of CFG, the potential exists for the calculation method to artificially increase the retained voltage on busbars, and consider a fault contribution that would not actually occur.

It is therefore proposed that the implementation of the equations (3) & (4), which govern the fault contribution in ENA G74, are slightly modified to include a threshold requirement, based on the retained voltage. If the retained voltage $\underline{Vret}$ is below the CFG setting *Vth*, then the fault contribution is considered, otherwise it is blocked. The revised formulation is shown in Equations (12) and (13) below.

$$\begin{cases} \Delta I_{CDP} = K_j \Delta u_j, if\ V_{ret} < V_{th} \\ \Delta I_{CDP} = 0, if\ V_{ret} \geq V_{th} \end{cases} \quad (12)$$

: if ΔI is below the maximum current set by I_{max} & $I_{qh}1/I_{qh}2$

$$\begin{cases} \Delta I_{CDP} = I_{maxj}, if\ V_{ret} < V_{th} \\ \Delta I_{CDP} = 0, if\ V_{ret} \geq V_{th} \end{cases} \quad (13)$$

:otherwise

VI. Conclusions & Further Work

The results of the analysis has shown that if there is a significant presence of CFG on the network, and particularly on a weak electrical network, then utilising the IEC 60909 fault current calculation method encounters problems due to the CFG increasing the retained voltage on the system, as the CFG behaves a constant current source, regardless of the magnitude of the fault, and increases the retained voltage to unrealistic values. The use of the ENA G74 method, whilst based on a slightly different methodology, attempts to address this issue as it utilizes a more accurate method for modelling the CFG within the network. However, it does not correctly consider that the CFG fault contribution is only triggered if the retained voltage falls below a threshold set within the inverter.

It is important to recognise that the constant current output of a CFG and its impact to increase the retained voltage on a system is a real phenomenon, but fault calculation must be validated to identify where the CFG response is triggered and assessed to identify where a retained voltage become non-credible. Both standards therefore have a significant potential for over-estimating a calculated fault level in a CFG dominated network. On larger meshed transmission networks, although the existing G74 method shows an improvement, it could lead to more significant over-estimation of network retained voltages, due to a cumulative effect of CFG.

Further work in this area would be to benchmark the results against test networks and larger meshed systems, and to carry out dynamic time-based simulations, to validate more detailed models against the simplified static calculations. Additional areas to consider would be a more accurate representation of GFM type technology within the standards, and if an equivalent synchronous machine approach is suitable. Contact with the relevant technical committee to highlight the issue is also planned.

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