Effect of Type and Interconnection of DG Units in the Fault Current Level of Distribution Networks

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Abstract— Fundamental requirements for the connection of distributed generation resources to the network are not only power quality constraints, but also voltage regulation and the total fault level, which should remain below the network desired value. This constraint is often the main limiting factor for the interconnection of these resources to the grids. In the presented paper, the impact of installation of distributed resources in the distribution systems from the perspective of increase in the fault contribution will be discussed and comparative study will be performed to analyze the effect of type and interconnection of distributed generation unit on the fault current contribution of the distribution systems. Simulation results indicate that the increase in fault currents is often greater in the synchronous machine implementation versus a comparable inverter based design.

Keywords— Distributed Generation, Distribution System, Fault Current, Power Electronic.

NUMENCLATURE

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Definition</th>
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<tbody>
<tr>
<td>V</td>
<td>Bus RMS Voltage</td>
</tr>
<tr>
<td>φ</td>
<td>Bus Voltage angle</td>
</tr>
<tr>
<td>f</td>
<td>Network Frequency</td>
</tr>
<tr>
<td>P</td>
<td>Generator real power</td>
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<tr>
<td>Q</td>
<td>Generator reactive power</td>
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<tr>
<td>V₀</td>
<td>Instantaneous generator internal Voltage</td>
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<tr>
<td>φ₀</td>
<td>Generator Voltage angle</td>
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<tr>
<td>i₀</td>
<td>Instantaneous generator current</td>
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<tr>
<td>f₀</td>
<td>Generator Output Frequency</td>
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<tr>
<td>R₀</td>
<td>Generator internal resistance</td>
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<tr>
<td>X₀</td>
<td>Generator internal reactance</td>
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<tr>
<td>v_i</td>
<td>Instantaneous converter input Voltage</td>
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<tr>
<td>v_o</td>
<td>Instantaneous converter output Voltage</td>
</tr>
<tr>
<td>i</td>
<td>Instantaneous converter output current</td>
</tr>
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<td>v_{dc}</td>
<td>Converter DC link Voltage</td>
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<td>m</td>
<td>Converter magnitude modulation index</td>
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<tr>
<td>a</td>
<td>Converter angle modulation index</td>
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<tr>
<td>R_f</td>
<td>Filter resistance</td>
</tr>
<tr>
<td>X_f</td>
<td>Filter reactance</td>
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</table>

I. INTRODUCTION

The ever-increasing energy consumption has created increased interest in green power generation systems. Moreover, due to steady progress in power deregulation and utility restructuring, and because tight constraints are imposed on the construction of new transmission lines for long-distance power transmission, interest in distributed generation (DG) systems installed near load centers is increasing. The benefits provided by DGs are not only improved power quality and system reliability, but also loss reduction. However, if certain minimum standards for control, installation and protection are not maintained, power system operations may be adversely impacted by the use of DGs. Thus, DGs should meet various operating requirements of the utilities or the power system operators [1-5].

A fundamental requirement for the connection of DG resources to the network, besides voltage regulation and power quality constraints [6], is the total fault level, which is mainly obtained by the short-circuit contribution of both upstream grid and the DG, should remain below the network design value. This constraint is often the main limiting factor for the interconnection of DG units to the grids [7-10]. To facilitate the interconnection of DGs to a distribution system, standards are being developed [11, 12]. An engineering analysis is usually needed to assess the impact of the DG on the operation of the system [13-16].

Distribution systems are mainly characterized by power losses and a design short circuit capacity (SCC), i.e. a maximum acceptable fault current, related to the switchgear used and to the thermal and mechanical withstands capability of the equipment and utilities. In medium voltage (MV) and low voltage (LV) radial networks, the fault current contribution of the upstream grid is practically determined by the short-circuit impedance of the HV/MV or MV/LV transformers, which is selected as low as possible to improve voltage regulation and the overall power quality performance of the network. So, the short-circuit capacity of existing distribution networks, especially at the MV level, is close to the design value, leaving little margin for the connection of even moderate amounts of DG. Short-circuit calculations for switchgear selection and protection coordination are performed according to established national and international practices, most important and widely accepted being the ANSI/IEEE and IEC Standards [20-22].

The requirement of not exceeding the design short-circuit capacity should be satisfied at every point of the distribution system under maximum fault current conditions. In typical radial networks, fed by a HV/MV (or MV/LV) substation, this condition normally needs to be checked at the MV (or LV) bus bars of the substation. The contribution of individual DG sources, on the other
hand, reduces to a much smaller degree at remote network nodes, because their internal impedance is relatively high compared to the impedance of the network lines. The resulting fault level of distribution system is the pharos sum of the maximum fault currents from the upstream grid, through the step-down transformer, and the various generators (and possibly motors) connected to the network.

On account of the fact that the procedure of fault current limitation requires such a flexible and authentic device which can act rapidly. Due to their speed of response and flexibility, power-electronic (PE) converter systems of electronically-coupled DG units are the prime candidates to perform the require control and/or protection functions to meet the micro-grid objectives [6].

The goal of this paper is to attempts to compare effect of different DG sources and their interconnection to the grid in the contribution to increase the fault level of distribution systems based on a general dynamic model for DG units and their interconnections. The models have been developed in MATLAB/Simulink environment based on reference frame theory [28]. Then, effect of type and interconnection of DG units has been studied and results have been presented.

II. DG INTERCONNECTION INTERFACES

The electric output of DG units can be connected to the electrical power system via three basic interconnection interfaces. The block diagram of different interconnections of DG units has been shown in Fig. 1.

A. Synchronous Generator

Synchronous generators are used with most reciprocating engines and most high power turbines (gas, steam, and hydro). In a synchronous machine, the electrical frequency of induced voltage depends on the speed of rotation of the generator.

B. Induction Generator

Induction generators are typically only used in wind turbines and some low-head hydro applications. There are two types of rotor designs available: cage-rotor and
wound-rotor. The advantage of the cage-rotor induction generator is the lower cost compared to a synchronous generator, but induction generators require a supply of VARs either from capacitors, from the electric power system, or from power electronic-based reactive compensator to operate [29]. The doubly fed induction generator (DFIG) has added advantages, however, is more expensive.

C. Power Electronic Interfaced DG Units

With the fast development of solid-state-based packages, power electronic (PE) devices can now convert almost any form of electrical energy to a more desirable and usable form. Another benefit of PE covers is their extremely fast response times. PE interfaces can respond to power quality events or fault conditions within the sub-cycle range. PE-based inverters are widely used in micro turbines generators (MTG), fuel cells (FC), photovoltaic (PV) and fuel cell combined with an energy storage system like battery-, some wind turbines, and energy storage systems. This high-speed response can enable advanced applications such as the operation of intentional islands (micro grids) for high-reliability applications and reducing fault level currents of distributed generation [8].

The PE interface can also contain protective functions for both the distributed energy system and the local electric power system that allow paralleling and disconnection from the electric power system. These functions would typically meet the IEEE Std. 1547 interconnection requirements [11], but can be set more sensitive depending on the situation and utility interconnection requirements. Fig. 1 shows block diagram of the DG system and PE.

III. MODELLING ON DG UNITS

Fig. 2 shows the system under study which involves different type of DGs connected to the grid via different methods. The type and interconnection methods of DGs are presented in Table 1.

### Table 1. Type and Interconnection Methods of DGs

<table>
<thead>
<tr>
<th>DG No.</th>
<th>Type of DG</th>
<th>Interconnection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Diesel generator</td>
<td>Directly</td>
</tr>
<tr>
<td>2</td>
<td>Micro turbine</td>
<td>AC-DC-AC</td>
</tr>
<tr>
<td>3</td>
<td>Micro turbine</td>
<td>Matrix converter</td>
</tr>
<tr>
<td>4</td>
<td>PV</td>
<td>DC-AC inverter</td>
</tr>
<tr>
<td>5</td>
<td>Wind farm</td>
<td>AC-DC-AC</td>
</tr>
<tr>
<td>6</td>
<td>Fuel cell</td>
<td>DC-AC inverter</td>
</tr>
<tr>
<td>7</td>
<td>Wind farm</td>
<td>Directly</td>
</tr>
<tr>
<td>8</td>
<td>Fuel cell + battery</td>
<td>DC-AC inverter</td>
</tr>
</tbody>
</table>

DG1 which is connected to the grid shown in Fig. 2 is a diesel generator and the transient model mentioned in [28] has been used to model its transient behavior during the fault.

### A. Modeling of DG1

### B. Modeling of DG2

Fig. 1 d demonstrates a block diagram of DG2. The three-phase voltage equation of the generator-side is

\[ v_{pg2} = R_{g2} i_{pg2} + L_{g2} \frac{d}{dt} (i_{pg2}) + w_{pg2} \]  

(1)

where subscript \( p \) denotes \( a, b \) and \( c \) phase components of variables, \( d \) is the \( \frac{d}{dt} \) operator, \( R_{g2} = \text{diag}(R_{g2}, R_{g2}, R_{g2}) \) and \( L_{g2} = \text{diag}(L_{g2}, L_{g2}, L_{g2}) \). The voltage vectors of the generator and the converter input side are denoted by \( v_{pg2} \) and \( v_{pi2} \) respectively.

To transfer the generator-side instantaneous variables to a rotating reference frame (RRF), transformation matrix is chosen such that \( d \) and \( q \) the and components of the generator-side current are proportional to the converter instantaneous real and reactive power components [30,31]. Thus, the generator-side variables are transferred to a \( dq0 \) frame by

\[ f_{q2} = K_{q2} f_{p2} \]  

(2)

where subscript \( t \) denotes \( q, d \) and \( o \) components of variables and the transformation matrix is

![Fig. 2. Test System](image-url)
\[ K_g = \begin{bmatrix} \cos(\theta_g) & \cos\left(\theta_g - \frac{2\pi}{3}\right) & \cos\left(\theta_g + \frac{2\pi}{3}\right) \\ \sin(\theta_g) & \sin\left(\theta_g - \frac{2\pi}{3}\right) & \sin\left(\theta_g + \frac{2\pi}{3}\right) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \]  

(3)

\[ \theta_g(t) = \theta_0 + \omega_g t + \theta_2 \]

(4)

where \( \theta_2 \) is phase-angle of the generator phase-a voltage and \( \omega_g \) is the generator angular frequency. Substituting for \( V_{mg} \), \( \omega_g \), and \( \theta_2 \) from (2) in (1), yields

\[ V_{mg}^{-1} g_{21} = R_{g2} g_{21}^{-1} \omega g_{21} + L_{g2} g_{21}^{-1} i_{g2} + K_g^{-1} e_{21} \]

(5)

Multiplying both sides of (5) by \( K_g \), we have

\[ V_{mg} = R_{g2} g_{21} + L_{g2} g_{21}^{-1} i_{g2} + K_g^{-1} e_{21} + v_{g2} \]

(6)

where

\[ v_{g2} = V_{mg} M \]

(7)

\[ K_g^{-1} g_{21} = \omega g_{21} \]

(8)

\[ M = \begin{bmatrix} 0 & 1 & 0 \end{bmatrix} \]

(9)

\[ N = \begin{bmatrix} 0 & 0 & 0 \end{bmatrix} \]

(10)

The equation set representing the circuit between the inverter and the micro-grid system of Fig. 2, in RRF, is

\[ v_{po} = R_{f2} i_{po} + L_{f2} \frac{d}{dt}(i_{po}) + v_{po} \]

(21)

where subscript \( p \) denotes a, b and c phase components of variables, \( R_{f2} = \text{diag}(R_{fa}, R_{fb}, R_{fc}) \), \( L_{f2} = \text{diag}(L_{fa}, L_{fb}, L_{fc}) \). Similar to the discussions presented for the generator-side circuit equations of Fig. 2, i.e., (1) to (19) that finally concluded (20), we transfer (21) to a frame and deduce

\[ V_{mg} M = R_{f2} i_{po} + L_{f2} \frac{d}{dt}(i_{po}) + v_{po} \]

(22)

where subscript \( t \) denotes \( q, d \) and \( 0 \) components of variables, \( \omega_0 \) is the grid angular frequency, \( V_{mg} \) and \( \theta_2 \) are the amplitude and phase angle of DG2 output terminal voltage respectively and

\[ A_{mu} = \frac{2}{V_{de}} \left( (L_{f2} \omega_0 i_{q2} + R_{f2} i_{q2})^2 + (V_{mg} - L_{f2} \omega_0 i_{d2} + R_{f2} i_{d2}) \right)^{1/2} \]

(23)

\[ \alpha_{mu} = \theta_g - \left( \frac{L_{f2} \omega_0 i_{q2} + R_{f2} i_{q2}}{V_{mg} - L_{f2} \omega_0 i_{d2} + R_{f2} i_{d2}} \right) + \theta_2 \]

(24)

The dq-based, fundamental-frequency, model of DG2 unit is provided by (20) and (22), and can be used for the steady-state and dynamic analysis of the unit.

C. Modelling of DG3

Fig. 1c demonstrates a block diagram of DG3 which is connected to the micro grid shown in Fig. 2. The three-phase voltage equation of the grid-side of DG3 is

\[ v_{p3} = R_{f3} i_{p3} + L_{f3} \frac{d}{dt}(i_{p3}) + v_{po} \]

(25)

where subscript \( p \) denotes \( a, b \) and \( c \) phase components of variables, \( d \) is the \( d/dt \) operator, \( R_{f3} = \text{diag}(R_{fa}, R_{fb}, R_{fc}) \), \( L_{f3} = \text{diag}(L_{fa}, L_{fb}, L_{fc}) \) and \( v_{po} \) and \( v_{p3} \) are three phase voltages at the converter output and output terminals, respectively.

The abc variables in (25) are transformed to a rotating reference frame by

\[ v_{a3} = K_3 i_{p3} \]

(26)

where subscript \( t \) denotes \( t \) components of variables and the transformation matrix is

\[ K_3 = \begin{bmatrix} \cos(\theta_3) & \cos(\theta_3 - \frac{2\pi}{3}) & \cos(\theta_3 + \frac{2\pi}{3}) \\ \sin(\theta_3) & \sin(\theta_3 - \frac{2\pi}{3}) & \sin(\theta_3 + \frac{2\pi}{3}) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \]

(27)

\[ \theta_3(t) = \theta_0(t) + \omega_3 t + \theta_2 \]

(28)

\( \theta_2 \) is phase-angle of the generator phase-a voltage at DG3 terminal. Substituting for abc variables based on (26) in (25), yields

\[ v_{a3} = R_{f3} i_{a3} + L_{f3} \frac{d}{dt}(i_{a3}) + K_3 d\theta_3 + v_{po} \]

(29)

where

\[ v_{a3} = V_{mg} M \]

(30)

\[ K_3 d\theta_3 = \omega_0 N \]

(31)

Matrices \( M \) and \( N \) are defined by (9) and (10), respectively and \( V_{mg} \) is the voltage amplitude at DG3.
output terminal. The fundamental-frequency switching functions of the matrix converter are [32]:

\[
\begin{align*}
S_1(t) &= \frac{2}{3} A_{m1} \cos \left( \theta_{a1}(t) - \frac{2\pi}{3} \right) \\
S_2(t) &= \frac{2}{3} A_{m1} \cos \left( \theta_{a2}(t) - \frac{2\pi}{3} \right) \\
S_3(t) &= \frac{2}{3} A_{m1} \cos \left( \theta_{a3}(t) - \frac{2\pi}{3} \right)
\end{align*}
\]

(32)

where \( \theta_{a1}(t) = \theta_{a0} + \omega_{ac}. \) Assuming that the input terminal voltages of the converter are

\[
\begin{align*}
V_{a0}(t) &= \frac{1}{2} V_{max} \sin(\omega_{ac} t - \theta_{a}) \\
V_{b0}(t) &= \frac{1}{2} V_{max} \sin(\omega_{ac} t + \frac{2\pi}{3} - \theta_{a}) \\
V_{c0}(t) &= \frac{1}{2} V_{max} \sin(\omega_{ac} t + \frac{2\pi}{3} - \theta_{a})
\end{align*}
\]

(33)

where \( \theta_{a1}(t) = \omega_{ac} t + \alpha_{a1} \), then the output phase-a voltage of the matrix converter is (30):

\[
v_{a0}(t) = [S_1(t) S_2(t) S_3(t)] \begin{bmatrix} V_{a0}(t) \\ V_{b0}(t) \\ V_{c0}(t) \end{bmatrix}
\]

(34)

Substituting for \( S_1, S_2 \) and \( S_3 \) from (32) and for \( V_{a0}, V_{b0}, \) and \( V_{c0} \) from (31) in (34), yields

\[
v_{a0}(t) = \frac{1}{3} V_{max} \sin(\omega_{ac} t + \alpha_{a0})
\]

(35)

where \( V_{max} = \alpha_{a0} V_{max} \) and \( \alpha_{a0} = \alpha_{a0} - a_{a0} \). Substituting for \( V_{a0}, V_{b0}, \) and \( V_{c0} \) based on (36) in (26), where and \( V_{max} \) and \( V_{a0} \) are 120 and 120 out of phase with respect to \( V_{a0} \), we have

\[
v_{a0} = \frac{1}{2} V_{max} \sin(\omega_{ac} t - \theta_{a}) \cos(\omega_{ac} t - \theta_{a}) 0^T
\]

(36)

Substituting for \( V_{a0}, K_{dc} (K_{dc}^t) \) and \( V_{b0} \) from (30), (31) and (36) in (29), yields

\[
-\dot{V}_{mg3} = R_f^d V_{mg3}^d + L_f^d \dot{V}_{mg3}^d + L_f^q V_{mg3}^q + L_f^q \dot{V}_{mg3}^q
\]

\[
-\dot{V}_{mg3} = \sin(\omega_{ac} t - \theta_{a}) \cos(\omega_{ac} t - \theta_{a}) 0^T
\]

(37)

The abc variables of G3, are transferred to a frame by

\[
v_{mg3} = K_{mg3} \begin{bmatrix} v_{mg3}^a \\ v_{mg3}^b \\ v_{mg3}^c \end{bmatrix}
\]

(38)

where

\[
K_{mg3} = \begin{bmatrix} \cos(\omega_{ac} t) & \cos(\omega_{ac} t + \frac{2\pi}{3}) & \cos(\omega_{ac} t + \frac{\pi}{3}) \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix}
\]

(39)

\[\theta_{a1}(t) = \theta_{a0} \cos(\omega_{ac} t + \theta_{a} t)
\]

(40)

\( \theta_{a1} \) is the phase-angle of the generator phase-a voltage. Similar to the discussion presented for (37), voltage equations of the generator-side circuit, in the dq0 frame, are

\[
\dot{V}_{mg3} = R_f^d V_{mg3}^d + L_f^d \dot{V}_{mg3}^d + L_f^q V_{mg3}^q + L_f^q \dot{V}_{mg3}^q
\]

\[
-\dot{V}_{mg3} = \sin(\omega_{ac} t - \theta_{a}) \cos(\omega_{ac} t - \theta_{a}) 0^T
\]

\[
-\dot{V}_{mg3} = \sin(\omega_{ac} t - \theta_{a}) \cos(\omega_{ac} t - \theta_{a}) 0^T
\]

(41)

where \( V_{mg3} \) and \( \theta_{a1} \) are the amplitude of internal voltage and the angular frequency of DG3, respectively. Usually, a capacitor is used at the input of the matrix converter to maintain the voltage. The capacitor current equation, is

\[i_{pc3} = C_{g3} \frac{d}{dt} V_{pc3}(t)
\]

(42)

Substituting for abc variables from (38) in (42), yields

\[
i_{pc3} = C_{g3} \frac{d}{dt} (V_{pc3}(t) + C_{g3} \theta_{a3} W_{g3})
\]

(43)

In (42) and (43), subscripts \( p \) and \( f \) denote \( a, b, c \) and \( q, d, \theta \) variables, respectively. Equations (37), (41), and (43) represent a fundamental-frequency dq0-based model of the DG3 unit and can be used for the dynamic analysis of the DG unit.

D. Modelling of DG4

Fig. 1b demonstrates a block diagram of DG4 which is connected to the micro grid shown in Fig. 2. The PV system can be represented by a series combination of a DC source and internal resistance and inductance. The DC voltage at the inverter DC-side is

\[
v_{d4}(t) = v_{o4}(t) - (R_{g4} + dL_{g4}) \dot{V}_{o4}(t)
\]

(44)

the three phase voltages at the inverter ac-side are

\[
v_{a4}(t) = \frac{1}{2} A_{max} \sin(\omega_{ac} t + \theta_{a})
\]

(45)

\[
v_{b4}(t) = \frac{1}{2} A_{max} \sin(\omega_{ac} t - \frac{2\pi}{3})
\]

(46)

\[
v_{c4}(t) = \frac{1}{2} A_{max} \sin(\omega_{ac} t + \frac{2\pi}{3})
\]

(47)

where \( \theta_{a1}(t) = \omega_{ac} t + \alpha_{a1} \). Substituting for \( v_{a4}, v_{b4}, \) and \( v_{c4} \) from (45) to (47) in (2), yields

\[
v_{a4} = \frac{1}{2} A_{max} \sin(\omega_{ac} t + \theta_{a})
\]

(48)

The equations representing the circuit between the inverter and terminal of the micro-grid system of Fig. 2, in the RRF, are

\[
v_{pz4} = R_f^d V_{mz4}^d + L_f^d \dot{V}_{mz4}^d
\]

(49)

where subscript \( z \) denotes \( a, b, c \) and \( p, q, R, L \) are the phase components of variables, \( R_f = \text{diag} \{R, R, R\} \) and \( L_f = \text{diag} \{L, L, L\} \). Like the discussions presented for the generator-side circuit equations, i.e., (40) to (45), we transfer (45) to a RRF and so we have

\[
-\dot{V}_{mg4} = R_f^d V_{mg4}^d + L_f^d \dot{V}_{mg4}^d + L_f^q V_{mg4}^q + L_f^q \dot{V}_{mg4}^q
\]

\[
-\dot{V}_{mg4} = \sin(\omega_{ac} t - \theta_{a}) \cos(\omega_{ac} t - \theta_{a}) 0^T
\]

(50)

where \( \theta_{a1}(t) = \omega_{ac} t + \theta_{a} t \). Substituting for \( a, b, c \) and \( q, d, \theta \) variables, respectively. Equations (38), (39), and (42) represent a fundamental-frequency dq-based model of the DG2 unit is provided by (50), and can be used for the dynamic analysis of the unit.

E. Modelling of DG5

Modelling of DG5 has been performed using the induction generator’s model mentioned in [28] and also the modeling of AC-DC-AC conversion system mentioned in part B.

F. Modelling of DG6

Dynamic modeling of Fuel cell and the PE interface is like the PV model mentioned in part D with different parameter values.
DG UNITS CONTRIBUTIONS IN FAULT CURRENT OF THE SYSTEM

<table>
<thead>
<tr>
<th>No. of DG</th>
<th>Index 1 (PV)</th>
<th>Index 2 (FP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20.02</td>
<td>28.31</td>
</tr>
<tr>
<td>2</td>
<td>19.07</td>
<td>26.54</td>
</tr>
<tr>
<td>3</td>
<td>18.02</td>
<td>24.32</td>
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<tr>
<td>4</td>
<td>15.2</td>
<td>22.35</td>
</tr>
<tr>
<td>5</td>
<td>13.2</td>
<td>20.18</td>
</tr>
<tr>
<td>6</td>
<td>13.02</td>
<td>18.56</td>
</tr>
<tr>
<td>7</td>
<td>12.58</td>
<td>17.32</td>
</tr>
<tr>
<td>8</td>
<td>11.52</td>
<td>16.56</td>
</tr>
</tbody>
</table>

IV. SIMULATION RESULTS

The transient models of DG units discussed in section III have been implemented in MATLAB/Simulink environment and tested on a test system shown in Fig. 2. The goal of this simulation is to analyze the contribution of each DG unit in the fault and then compare them with different parameter values.

Table II compares the transient and steady state contribution of DG units in fault current in the grid. Results show that PE interface can be effective in fault current reduction in the grid having distributed resources.

V. CONCLUSION

In this paper, the impact of installation of distributed resources in the distribution systems from the perspective of increase in the fault contribution was discussed and comparative study was performed based on two indices to show the transient and steady state effect of fault current caused by DG units and also analyze the effect of type and interconnection of distributed generation unit on the fault current contribution of the distribution systems. Simulation results indicate that the increase in fault currents is often greater in the synchronous and induction machine implementation versus a comparable inverter based design.

REFERENCES


BIographies

Hamid Reza Baghaee (IEEE Student Member' 2008) received the BSc degree in Electrical Engineering from Kashan University in 2006. Currently he is graduate student of Power Engineering in Amirkabir University of Technology. His research interests are power system dynamic and control, HVDC & FACTS devices, Distributed Generation (DG) and application of Artificial Intelligence in power systems.

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