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Effect of load type on standalone micro grid fault performance

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HIGHLIGHTS

- Paper investigated effect of different load types on standalone MG fault performance.
- Constant power, constant impedance, and constant current static loads are considered.
- Dynamic load (rotating load) effect has been investigated.
- Results proved that the load type dominate standalone MG fault performance.

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ABSTRACT

This paper studies the influence of the load type on the fault performance of the standalone Micro Grid (MG). Different load types (static and dynamic) are considered to show their effects on the standalone MG fault behavior. Specifically, the effects of constant power static loads, constant impedance static loads, and constant current static loads are analyzed. Also, effects of dynamic (rotating) loads are highlighted. Results show, that the rotating loads have dominant effects on the fault performance of the MG during the standalone (islanded) mode. Furthermore, rotating loads cause fault currents and touch voltages three times the values associated with the static loads. Consequently, the employed protective devices with the rotating loads MG must be rated three times larger than the employed protective devices with the static loads MG. Also, the time settings of the MG protection devices are highly influenced with the load type. For static load MG, it is equal to 250% of the rotating loads MG protection devices time settings. The three types of static load show different impacts on islanded MG fault performance. Constant power static load has the highest effect compared to the other two static load types (namely, constant impedance and constant current static loads). The results obtained in this study provide a guide for the MG protection designers and planners to consider the effects of load type on the MG protection devices rating and setting.

1. Introduction

Micro-Grid (MG) is a very small power network which contains different types of micro sources or distributed generations (DGs) such as photovoltaic (PV), wind generation system, fuel cell, micro turbine, and storage devices (flywheel, batteries, super capacitors, ...) [1–3]. The MG network is designed to run in both standalone (islanded) and grid connected modes [1–3]. There are big differences between the standalone MG and the conventional power grid performance. The differences are due to that all the MG Distributed Generators (DGs) do not work in the same way like the synchronous generators in the conventional power grids [4,5]. Each of the MG DGs (PV, fuel cell, micro turbine, wind turbine, flywheel, ...) has its own characteristics and individual performance. In addition, most distributed generators (DGs) are interfaced electronically with the MG through power electronic inverter [6]. Based on the aforementioned facts, the standalone MG networks under any disturbance or fault condition have its own individual behavior and performance.

The MG loads can be classified to sensitive (critical) loads (such as surgery room operation in hospitals), and non-sensitive (non critical) loads. Alternatively, the MG loads can be classified according to their characteristics and behavior to static and dynamic (rotating) loads.

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Nomenclature

Acronyms

DG	Distributed Generator
DFIG	Double Fed Induction Generator
FCWG	Full Converter Wind Generator
MG	Micro Grid
MGCC	Micro Grid Central Control
p.u.	per unit
PV	photovoltaic
TDS	Time Deal Setting

Parameters

X_m	magnetizing reactance (Ω)
$X_{S\sigma}$	stator leakage reactance (Ω)
$X_{r\sigma}$	rotor leakage reactance (Ω)
X_S^-	transient stator reactance (Ω)
X_r^-	transient rotor reactance (Ω)
R_S	stator resistance (Ω)
R_r	rotor resistance (Ω)

Greek symbols

α	voltage phase angle for a given phase
σ	leakage factor
τ_S^-	stator time constant (s)
τ_r^-	rotor time constant (s)
ω	angular speed (p.u.)
Δf	frequency deviations (Hz)

Variables

a	active power model constant
b	reactive power model constant
f	frequency (Hz)
$i_{S,\max}$	maximum stator fault current (A)
I_S	stator current (A)
I_r	rotor current (A)
k_{pf}	ratio of active power variation with freq.
k_{qf}	ratio of reactive power variation with freq.
P	active power (W)
P_o	active power at initial voltage (W)
$p_1 - p_5$	general active power model constants
$q_1 - q_5$	general reactive power model constants
Q	reactive power (VAr)
Q_o	reactive power at initial voltage (VAr)
T	period time (s)
t	time (s)
S	rotor slip
V_S	stator voltage (V)
$\overline{V}$	ratio of voltage to initial value
ZIP	constant impedance, current and power loads

The MG performance and applications issues are addressed in the literature. In [7], MG with renewable energy sources has been employed for water treatment. Economic analysis and optimal energy management models for MG systems are presented and described in [8]. MG protection under fault disturbance is one of the widely investigated issues during the last few years. An adaptive scheme for MG network protection has been proposed in [9]. The proposed adaptive protection system does not require any communication signals between the MG Central Controller (MGCC) and the protective relays. It employs a voltage measurement method to distinguish between fault occurrence and overload conditions in standalone MG. The work in [10] proposed a novel adaptive protection system based on advanced communication network between the MG Central Controller (MGCC) and digital protective relays inserted at all MG buses. In this scheme, the settings of the protection relays is updated periodically to adapt and suite the variable operating conditions of the standalone MG. A new scheme for MG protection based on voltage measurements is proposed in [11]. The voltage of the DG in the MG is measured and transferred to a DC component by using the d–q transformation. An admittance protection relay with inverse time tripping characteristics is proposed in [12,13]. The proposed protection relay can differentiate between the fault disturbance and the overload conditions. Moreover, the proposed scheme in [12,13] is able to isolate the MG faulted parts during both grid connected and islanded modes. MG protection using differential protection schemes and symmetrical components is proposed in [14]. The proposed technique is able to detect most popular faults in the MG.

In [15], the fault currents in networks with different types of DGs have been calculated. An adaptive system for protecting the MG which runs in both grid connected and islanded modes has been designed in [16]. In [17], the effects of MG renewable micro sources on short circuit capacity of the hosting distribution networks have been estimated. MG protection during the utility voltage sags has been discussed and investigated in [18]. In [19,20], the authors developed and tested three earthing systems for MG network protection during both standalone and grid connected modes. Also, the most suitable earthing system is selected based on the results of [19,20]. Three fault ride through controllers for wind generation system runs in the standalone MG are designed and tested in [21,22]. In [23], different wind generation system types effects on MG fault performance during both standalone and grid connected modes are investigated in detail.

According to the authors' knowledge, there is no study in the literature addresses the effects of the MG load type on the fault performance especially at the standalone mode which is the most vulnerable mode. The research conducted so far considers the MG loads as constant power static loads. Other important load types like rotating loads (induction motors) are not addressed yet. This paper analyzes and investigates the influences of different load types on the standalone MG fault performance. The main load types (rotating and static loads) are considered. In addition, the effects of the different static loads (constant power, constant impedance, and constant current) are also analyzed and investigated.

On the following, only the standalone mode is considered. During the grid connected mode, the main power grid injects a huge fault current which makes any factor (DGs types, load types, MG topology, fault location, ...) has a negligible influence on the MG fault performance.

The rest of the paper is organized as follows: Section 2 shows the MG layout, the suitable earthing system, and a brief description of the DGs electronic interfacing. Section 3 presents a detailed analysis and modeling of the different load types (static and rotating) and their performance under disturbance and fault events. Section 4 presents the results obtained for different load types and summarizes the salient points of the results. Conclusions are reported in Section 5.