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Minimizing of Fault Current Using SFCL with PV Based Distribution Generation Scheme

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Abstract:

Renewable energy sources play an important role in rural areas where the power transmission from conventional energy sources is difficult. Other advantages of renewable energy sources are clean, light and does not pollute atmosphere. In order to meet the required load demand, it is better to integrate the renewable energy sources with the DG system. The main objective of this paper is to introduce a superconducting fault current limiter to keep the energy storage system from disconnecting from the grid when ground faults occur. The possible advantages of Superconducting Fault Current Limiter (SFCL) as a means to limit the adverse effect of DG on distribution system protection and their effectiveness will be demonstrated. However, the application of the SFCL in the power system affects the protective coordination of the existing protective devices and can deviate their operation time from the original one. Therefore, the study on the protective coordination considering the introduction of the SFCL is necessary prior to its installation is applied for Micro grid application consists of renewable energy sources with PV Source. The simulation results are obtained using MATLAB/SIMULINK software.

I.INTRODUCTION:

Renewable energy sources (RESs) have experienced a rapid growth in the last decade due to technological improvements, which have progressively reduced their costs and increased their efficiency at the same time [1]. Moreover, the need to depend less on fossil fuels and to reduce emissions of greenhouse gases, requires an increase of the electricity produced by RESs. This can be accomplished mainly by resorting to wind and photovoltaic generation, which, however, introduces several problems in electric systems management due to the inherent nature of these kinds of RESs [2]. In fact, they are both characterized by poorly predictable energy production profiles, together with highly variable rates.

As a consequence, the electric system cannot manage these intermittent power sources beyond certain limits, resulting in RES generation curtailments and, hence, in RES penetration levels lower than expected. A distribution system is a medium-voltage power system. Their configuration can be arranged in radial, loop or meshed types. The reliability of a radial distribution system is lower than a loop and meshed ones, but most distribution systems are still arranged in radial type because of lower cost and easier operation. In practice, power engineers of utilities adopt the approach, load transfer, to improve the reliability of radial distribution systems. Because generating facilities were not allowed to be connected to utilities' distribution systems in the past, the conventional load transfer approach is very simple for a radial distribution system. Once a fault happens in a distribution feeder, the load supplied by the faulted distribution feeder is transferred to other health distribution feeders via switching devices.

Conventional protection devices installed for protection of excessive fault current in power systems, mostly at the high voltage substation level circuit breakers tripped by over-current protection relay which has a response-time delay resulting in power system to pass initial peaks of fault current. But, SFCL is a novel technology which has the capability to quench fault currents instantly as soon as fault current exceeds SFCL's current limiting threshold level [2]. SFCL achieves this function by losing its superconductivity and generating impedance in the circuit. SFCL does not only suppress the amplitudes of fault currents but also enhance the transient stability of power system [2].Up to now, there were some research activities discussing the fault current issues of smart grid [4].But the applicability of SFCLs into micro grids was not found yet. Hence, in order to solve the problem of increasing fault current in power systems having multiple micro grids by using SFCL technology is the main concern of this work.

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The utilization of SFCL in power system provide them most effective way to limit the fault current and results inconsiderable saving from not having to utilize high capacity circuit breakers. With Superconducting fault current limiters (SFCLs) utilize superconducting materials to limit the current directly or to supply a DC bias current that affects the level of magnetization of a saturable iron core. Being many SFCL design concepts are being evaluated for commercial expectations, improvements in superconducting materials over the last 20 years have driven the technology [3]. Case in point, the discovery of high-temperature superconductivity (HTS) in 1986drastically improved the potential for economic operation of many superconducting devices.

II. MODELING OF AN SFCL AND DISTRIBUTION POWER SYSTEM WITH AN ENERGY STORAGE SYSTEM:

A. Resistive SFCL Model:

An SFCL is one of the most promising current limiters to prevent the short-circuit current from increasing in magnitude owing to its rapid current limiting ability. Many models for an SFCL have been developed, such as resistive type, reactive type, transformer type, and hybrid type SFCLs [10], [13]. Among the various types of SFCLs, the resistive type SFCL is preferred because of its simple principle and compact structure of small size [11]–[13]. In this paper, we have modeled a resistive type SFCL using mathematical expressive equations.

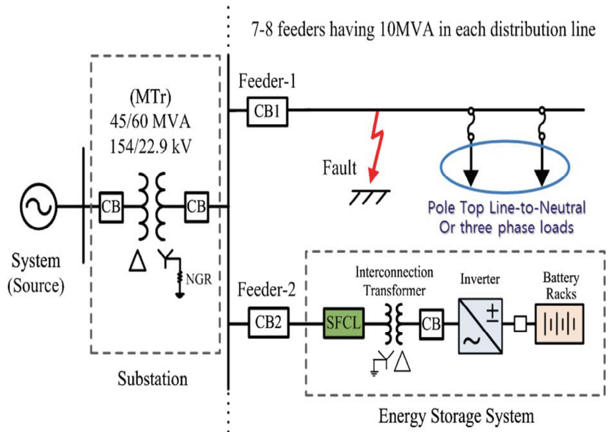

Fig.1.Power distribution system with an energy storage system

The time evolution of the SFCL impedance RSFCL as a function of time t is given by (1)–(3):

$$R_{SFCL}(t)=R_n\left[1-exp\left(-\frac{(t-t_0)}{T_F}\right)\right]^{\frac{1}{2}} \quad t_0\leq t<t_1 \tag{1}$$

$$R_{SFCL}(t)=a_1(t-t_1)+b_1 \tag{2}$$

$$R_{SFCL}(t)=a_2(t-t_2)+b_2 \tag{3}$$

Where Rn and TF are the convergence resistance and time constant, respectively. t0, t1, and t2 denote the quench-starting time, first starting time of recovery, and second starting time of recovery, respectively. In addition, a1, a2, b1, and b2 are the coefficients of the first-order linear function denoting the experimental results for the recovery characteristics of an SFCL. The parameter values are listed in Table I.

TABLE I SFCL MODELING PARAMETERS

SFCL	$R_n[\Omega]$	T_F	a_1	a_2	b_1	b_2
Value	8	0.01	-20	-50	5	3

B. Configuration of the Distribution System with an ESS:

A grid-scale ESS consists of a battery bank, control system, power electronics interface for ac-dc power conversion, protective circuitry, and a transformer to convert the ESS output to the transmission or distribution system voltage level. Fig. 1 shows a four-wire multi-grounded power distribution system with an ESS for simulation to analyze the effect of the SFCL application.

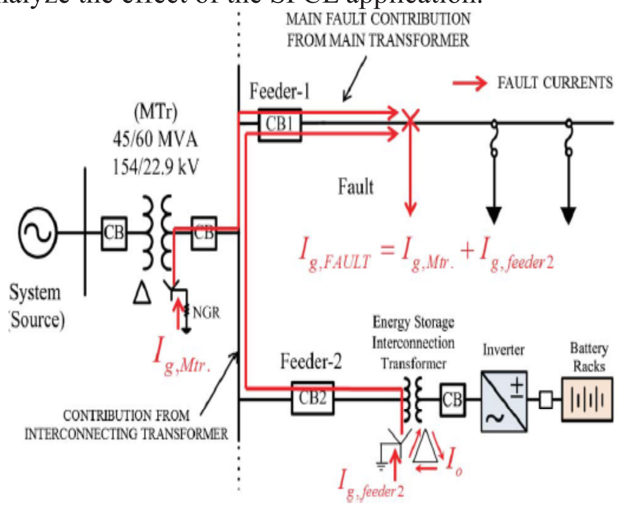

Fig.2. Effect of a single line-to-ground fault on an ESS interconnecting transformer without an SFCL

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The nominal voltage of this secondary system is 22.9 kV. There is a substation, 6–9 feeders, single- or three phase loads, and an ESS interconnecting transformer, as well as protection devices such as a circuit breaker (CB) and relay. There are two circuit breakers to clear the feeder faults through the operation of the relay. CB1 and CB2 are installed on feeder-1 and feeder-2, which is interconnected with the ESS.

The rated power of the ESS is assumed to be below 20 MW based on a Korea electric power corporation (KEPCO) guideline for a DG and corresponding generations interconnected with a distribution system. In order to integrate with the ESS, a grounded wye (utility side)-delta (ESS side) connection transformer is used in the analysis

III. SMART GRID:

Smart grids have become a topic of intensive research, development, and deployment across the world over the last few years. The engagement of consumer sectors—residential, commercial, and industrial—is widely acknowledged as a key requirement for the papered benefits of smart grids to be realized. Although the industrial sector has traditionally been involved in managing power use with what today would be considered smart grid technologies, these past applications have been one-of-a kind, requiring substantial customization.

The term "smart grid" refers to a reworking of electricity infrastructures—encompassing technology, policy, and business models—that is under way globally. Substantial amounts of government investment in several countries and regions have been devoted to smart grid research, development, and deployment. Smart grids are being pursued in order to address several challenges associated with today's power and energy systems, notably the following:

Greenhouse gas emissions and climate change. Fossil-fuel power stations are responsible for about 30% of all anthropogenic carbon dioxide emissions and about 20% of all greenhouse gas emissions; in both factors power generation is the single largest source (IPCC, 2007). With smart grids, substantially higher penetration of renewable, non-fossil-fuel generation sources is anticipated.

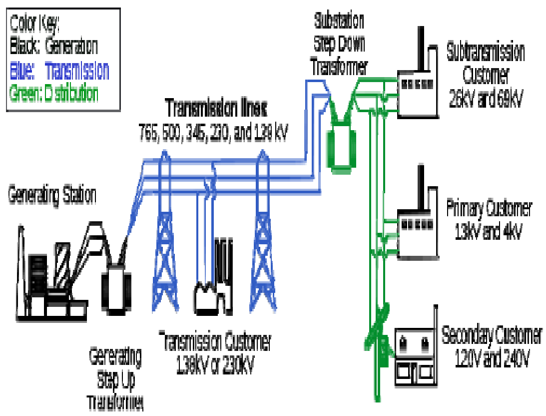

Fig.3 a simple diagram of electricity grids

Smart grid investments and developments are covering the entire electricity value chain: generation, transmission, distribution, markets, and, increasingly, consumers. The role of the end-use customer is in particular focus, primarily because the increasing penetration of wind and solar power is necessitating a more active role for energy management in homes, buildings and industries. The intermittency and unpredictability of renewable generation sources is in sharp contrast to traditional power generation. With power coming entirely or almost entirely from the latter assets, system operators have been able to keep the grid balanced by adjusting generation in real-time in response to demand variation. With unpredictability now extending to generation, "demand management" is essential.

IV. USING PV SOURCE:

A Photovoltaic (PV) system directly converts solar energy into electrical energy. The basic device of a PV system is the PV cell. Cells may be grouped to form arrays. The voltage and current available at the terminals of a PV device may directly feed small loads such as lighting systems and DC motors or connect to a grid by using proper energy conversion devices.

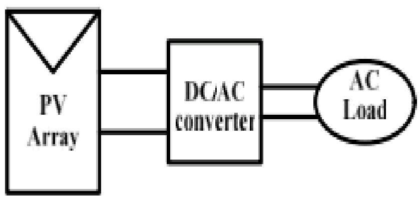

Fig.4. Block diagram representation of Photovoltaic system.

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This photovoltaic system consists of three main parts which are PV module, balance of system and load. The major balance of system components in this systems are charger, battery and inverter. The Block diagram of the PV system is shown in Fig.4.

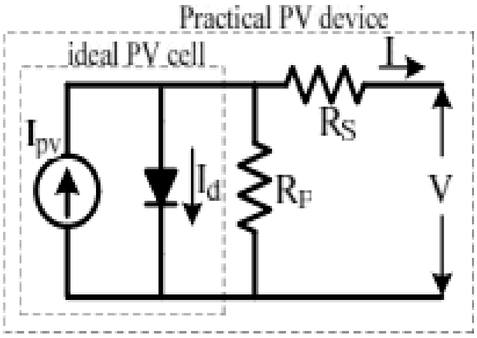

Fig.5. Practical PV device.

A. Photovoltaic cell A photovoltaic cell is basically a semiconductor diode whose p–n junction is exposed to light. Photovoltaic cells are made of several types of semiconductors using different manufacturing processes. The incidence of light on the cell generates charge carriers that originate an electric current if the cell is short circuited. The equivalent circuit of PV cell is shown in the fig.5. In the above figure the PV cell is represented by a current source in parallel with diode. Rs and Rp represent series and parallel resistance respectively. The output current and voltage form PV cell are represented by I and V. The I-V characteristics of PV cell are shown in fig.6. The net cell current I is composed of the light generated current IPV and the diode current ID.

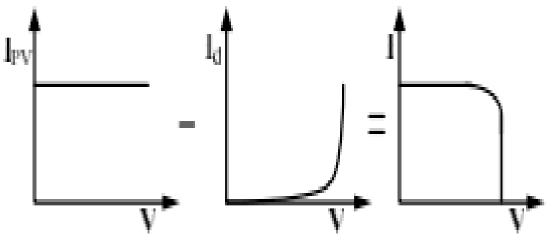

Fig.6. Characteristics I-V curve of the PV cell

V SIMULATION RESULTS AND DISSCUSION:

Here simulation is carried out in different cases, in that 1). Without Superconducting Fault Current Limiter and with PV source 2). With Superconducting Fault Current Limiter and with PV Source

Case 1: Without Superconducting Fault Current Limiter and PV source:

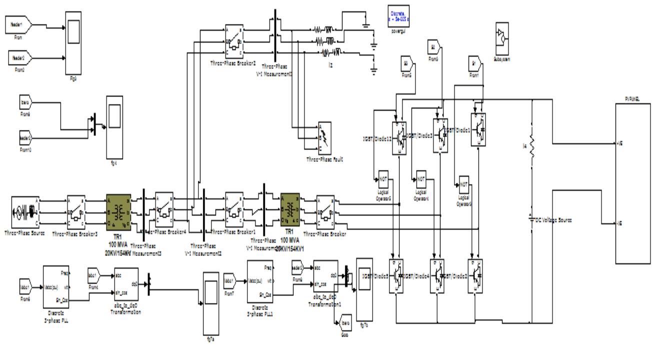

Fig.7 Matlab/Simulink Model of Proposed Grid Connected System without SFCL Topology

Fig.7 shows the Matlab/Simulink Model of Proposed Grid Connected System without SFCL Topology using Matlab/Simulink Tool.

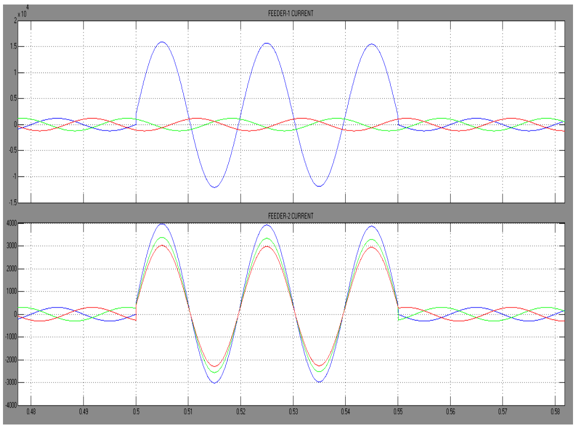

Fig.8 Feeder-1 & Feeder-2 Currents

Fig.8 Feeder currents caused by the single line-to ground fault in feeder-1 without an SFCL applied to the interconnecting transformer: (a) feeder-1 currents at CB1 and (b) feeder-2 currents at CB2.

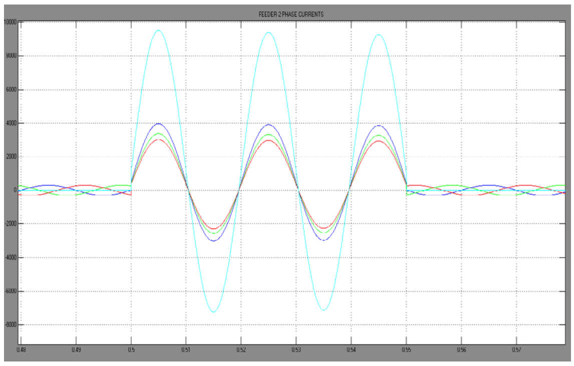

Fig.9 Feeder-2 Phase Currents

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Fig.9 Phase currents in feeder-2 and the zero-sequence current to the electrical ground of the ESS interconnecting transformer.

Case 2: With Superconducting Fault Current Limiter and with PV Source

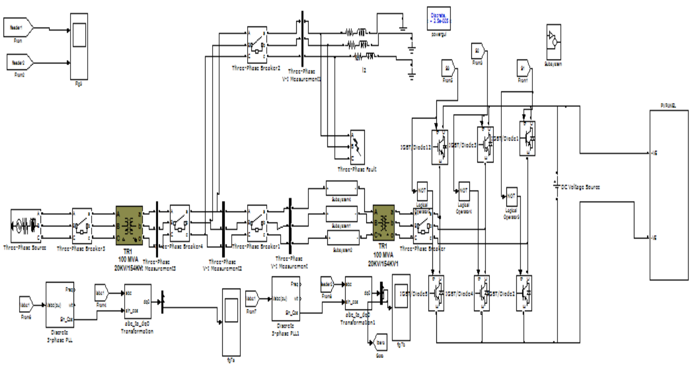

Fig.10. Matlab/Simulink Model of Proposed Grid Connected System with SFCL Topology with PV Source.

Fig.10.shows the Matlab/Simulink Model of Proposed Grid Connected System with SFCL Topology with PV Source using Matlab/Simulink Tool.

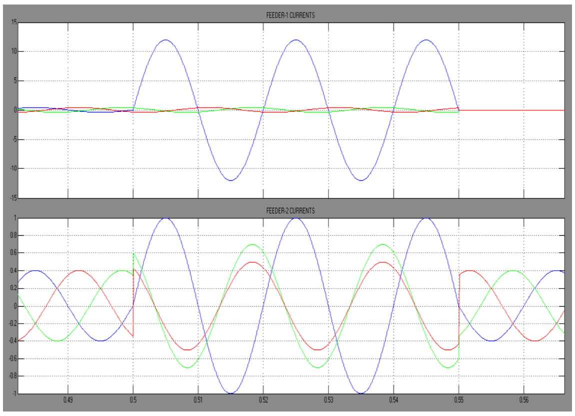

Fig.11. Feeder-1 & Feeder-2 Currents

Fig.11. Feeder currents caused by a single line-to-ground fault on feeder-1 with an SFCL applied to the interconnecting transformer with PV Energy Source: (a) feeder-1 currents at CB1 and (b) feeder-2 currents at CB2.

VI. CONCLUSION:

Renewable energy sources play an important role in rural areas where the power transmission from conventional energy sources is difficult.

These DG systems would be connected to the utility grid under normal operating conditions, but also have the additional capability to sustain a local system by sourcing power directly from the renewable energy sources and energy storage devices if necessary to make grid transmission level black- and brownouts seem transparent to the local system loads. The interconnecting transformer interfaced with an existing power system provides a new zero-sequence current path that is the cause of interruption between the power system and the ESS. The application of the SFCL to the interconnecting transformer solves the problem regarding protective coordination for an ESS. Therefore, an SFCL applied to the interconnecting transformer is used to improve the interconnection for a power system with energy storage by limiting the fault current. Of the two cases, we confirmed that the application of an SFCL to the interconnection transformer is an effective solution for sustainable interconnection.

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