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Improve Protection Concept of Transmission Line Based on Power Lines Carrier for microgrid

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Abstract. The modern energy supply system and the future ones include different intelligent devices. It also integrates renewable energy sources, the energy storage system, energy control, hybrid networks, and smart grids, as well as the broad application of information and communication technologies. The most important objective in the smart grid application is to improve the reliability of the network. Recent research has shown that the smart grid can improve the reliability of electrical systems, improve efficiency, and improve fault detection, and network repair. The proposal will reduce the duration of the interruption number of customers affected by the interruptions. Besides, Smart grid technology reduces energy loss and improves system efficiency. We conclude from this, the protection of the transmission line is necessary to improve the stability of the smart network. The protection of the faults becomes very difficult and the increasing delays in the multi-terminal planning system. The proposal offers a different solution to protect the transmission line and discusses the design of the protection system for the microgrid transmission line. This method is better than the distance protection because differential protection requires fewer input data and reduces the computation time. The most significant advantage of power line carrier communication (PLCC) technique from an economic standpoint, reduces a lot of time & money; also, it is reliable, easy to install and convenient.

1. Introduction

The smart grid will integrate all types of energy sources and adapts to all methods of production and distribution of energy to meet the future energy needs, the quality of energy transmission is the main objective of the Smart grid. Besides, the smart grid will provide advanced supervision and control using digital sensors, electronic switches, metering, smart energy and intelligent devices such as communication systems. Its data acquisition and control system include real-time and energy flow analysis. All the different types of renewable energy will be interconnected with the network regulator system to improve quality, stability, and reliability using intelligent and advanced equipment [1]. The provision of advanced technologies in smart grids requires smart protection systems to increase customer efficiency and reduce power outages. Using smart grids, energy consumers become active participants by control the balance of energy demand [2]. With the increase in energy demand and the expansion of renewable energy sources, energy network systems need to be moderated and improved.

Most of the distribution systems operate in a radial mode. Furthermore, the method of protection devices is designed to operate radially. By contrast, the circulation of energy within the smart grid can be bi-directional, which distributes DG connections to different locations. Therefore, conventional protection devices will be ineffective in protecting smart grids. Another difficulty is related to the low-fault current capacity of inverter devices within the smart grid [3].

The capacity is generally less than 50% of the rated current, except in cases where it is specifically designed for a high fault current capacity. Smart Grids are one of the solutions for the current energy crisis. The Smart grid is essentially a network that includes distributed generation sources, storage systems and loads are controllable, which can operate in a network or an isolated mode when a fault condition occurs. The smart grid offers benefits to consumers and society, including improving energy efficiency, minimising total energy consumption and improving service quality and reliability of energy supply [5]. Besides, the complexity level of the relationship between the microgrid and main grid depends on the level of penetration of DG in the main grid, the type and number of sources of generation and the location of the connection points. Increased penetration of distributed system generation in smart grids creates a series of technical problems in network operation; the main challenges for a smart grid are the protection system. The protection system must react quickly and positively to the faults of the main and microgrid grid and must isolate the faults from the main network as soon as possible [4].

The capability to maintain synchronisation after moving to the island process should be improved, which is extremely important to the point of view of stability. Arise some protection issues in the microgrid when the integration of DG with the distribution network, due to the change of the current level of network errors, the possibility of the false tripping, relay coordination loss [5]. A protection problem arises from the inverter devices in the Island mode because inverter sources limited by silicon device ratings. If used in a microgrid to improve service continuity, the protection of the distribution network must be modified. For detection of the defective part of network devices when used for automatic operation, which is done by disconnecting the defective part quickly and automatically reconfiguring the network as needed. The solution to problems arising from the bi-directional power flow and low levels of the fault current in a micro-grid and ensuring safe and reliable operation [6].

2. Basic Overview of Differential Protection

In reality, the proposal is a reliable method for the protection system. Since each current transformer and circuit breaker can only declare a line, it is usually protected by the use of two side current transformers and circuit breakers. The currents of both sides are compared. Under normal conditions or for defects outside the protected area, the current Bus-bar1 is equal to the current Bas-bar2. Thus, the currents in the secondary current transformer are equal; no current flows through the relay current. If a fault occurs in the protection zone, the secondary transformer current of Bas-bar1 and Bas-bar2 are not the same, and there is a current flowing through the relay current, as shown Figure1. The differential protection ratio, by using a multi-slope feature of the relay, is inserted into the new relay for its excellent compromise between reliability and sensitivity. The components of the relay compare the different current (also called operating current) and the restraining current as are expressed in eqn. (1,2)[7],[8].

$$I_{diff} = |I'_{As} + I'_{Bs}| \tag{1}$$

$$I_{bias} = (|I'_{As}| + |I'_{Bs}|)/2 \tag{2}$$

I'_{As} and I'_{Bs} are secondary CT phasor current. To provide a flexible and reliable operation the relays have two stages (low and high). A typical feature of the differential protection is shown in Figure 2.

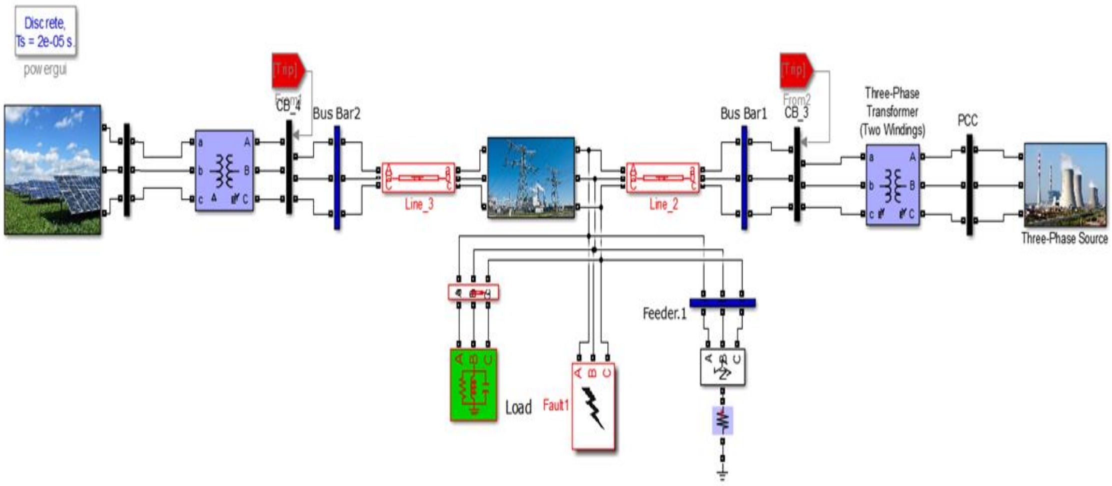

Figure 1. Proposed line differential protection solution for smart grid

$$|I_{bais}| < I_{bias1} \text{ and} |I_{diff}| > K_1 * |I_{bias}| + I_{diff1}$$
$$|I_{bias}| >= I_{bias1} \text{ and} |I_{diff}| > K_2 * |I_{bias}| - (K_2 - K_1) I_{bias1} + I_{diff1} \quad (3)$$

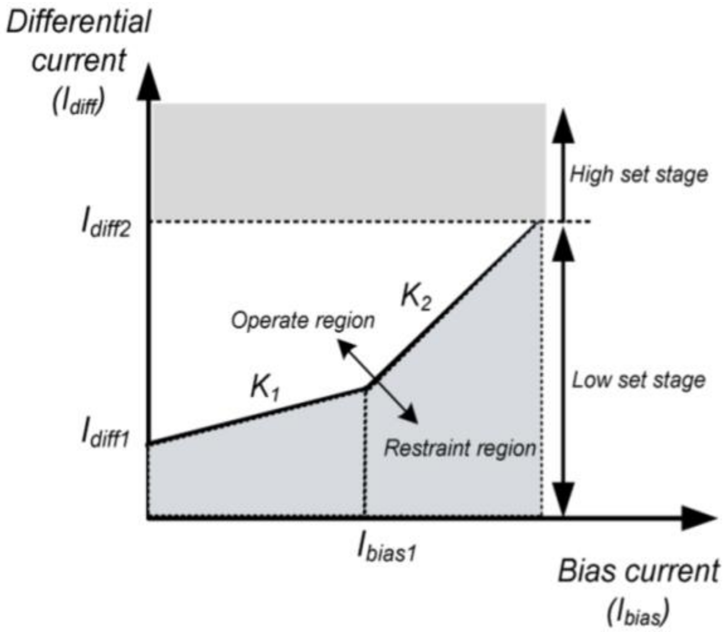

Figure 2. Differential relay Characteristic

3. Principle of Proposed Differential Protection

By comparing the vector currents on both sides of the transmission line, the main operation of the differential current protection relay is realised. Under normal circumstances, without possible fault or phase change, the magnitude and the phase of the currents in both sides should be the same. When there is a difference between them, it may be an internal fault. Figure 2 shows a single-phase current differential protection system. The wire carrying current from the CT called a pilot wire for the current transformer A, the pilot wire is carrying current equal to,

$$I_{AS} = a_A I_p - I_{Ae} \quad (4)$$

Where, a_A is the conversion ratio for CT A
I_{Ae} is the secondary excitation current for CT A

Regarding the ratio, aA= aB= a , relay operating current Iop , and the equation for current transformer B is:

$$I_{BS} = a_B I_p - I_{Be} \tag{5}$$

Where, a_B is the conversion ratio for CT B
I_{Be} is the secondary excitation current for CT B

$$I_{op} = I_{Ae} - I_{Be} \tag{6}$$

$$I_{op} = a(I_{f1} + I_{f2})I_{Ae} - I_{Be} \tag{7}$$

The equations give the uniform distribution of the line shown in Figure 3, The distribution of current along the transmission line and voltage:

$$-\frac{\partial u}{\partial x} = r_o i + l_o \frac{\partial i}{\partial t} \tag{8}$$

$$-\frac{\partial i}{\partial x} = g_o u + c_o \frac{\partial i}{\partial t} \tag{9}$$

where, co shunt capacitance (F/km), go the shunt leakage Conductance (S / km), Io in series inductance (H/km) and ro is a Series resistance (Ω /km). after reducing the equation (5) and (6) to its frequency domain, After reducing equations (5) and (6) to their frequency domain, the output is as follows:

$$\begin{bmatrix} U_m \\ I_m \end{bmatrix} = \begin{bmatrix} ch(\gamma l_{nm}) & -Z_c sh(\gamma l_{nm}) \\ sh(\gamma l_{nm})/Z_c & -ch(\gamma l_{nm}) \end{bmatrix} \begin{bmatrix} U_n \\ I_n \end{bmatrix} \tag{10}$$

Where,
sh(.) and ch(.) = Hyperbolic function
Zc = Characteristic impedance
γ = The propagation constant both are freqency dependent
l_{nm} = Distance from end to end m
When considering the constant characteristic of impedance and propagation, by applying the pre-conversion method to the sequence components of the current, the sub-indices "0", "1" and "2" are described as zero, positive and negative sequences, respectively.

$$I_{mk0} = I_{m0} ch(\gamma_0 l_{mk}) - \frac{U_{m0}}{Z_{c0}} sh(\gamma_0 l_{mk}) \tag{11}$$

$$I_{mk1} = I_{m1} ch(\gamma_1 l_{mk}) - \frac{U_{m1}}{Z_{c1}} sh(\gamma_1 l_{mk}) \tag{12}$$

$$I_{mk2} = I_{m2} ch(\gamma_1 l_{mk}) - \frac{U_{m2}}{Z_{c2}} sh(\gamma_1 l_{mk}) \tag{13}$$

$$I_{nk0} = I_{n0} ch(\gamma_0 l_{nk}) - \frac{U_{n0}}{Z_{c0}} sh(\gamma_0 l_{nk}) \tag{14}$$

$$I_{nk1} = I_{n1} ch(\gamma_1 l_{nk}) - \frac{U_{n1}}{Z_{c1}} sh(\gamma_1 l_{nk}) \tag{15}$$

$$I_{nk2} = I_{n2} ch(\gamma_1 l_{nk}) - \frac{U_{n2}}{Z_{c2}} sh(\gamma_1 l_{nk}) \tag{16}$$

Where,
l_{mk} and l_{nk} = Distance of point k from end m and n respectively.
Where,
$a = e^{j2\pi/3}$

$$\begin{bmatrix} I_{mka} \\ I_{mkb} \\ I_{mkc} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} I_{mk0} \\ I_{mk1} \\ I_{mk2} \end{bmatrix} \tag{17}$$

Similarly, the relation for current is as below :

$$\begin{bmatrix} I_{nka} \\ I_{nkb} \\ I_{nkc} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} I_{nk0} \\ I_{nk1} \\ I_{nk2} \end{bmatrix} \tag{18}$$

The fault is outside the protected area or there is no fault in the system, and then the phase current should be satisfied.

$$I_{mk\emptyset} = -I_{nk\emptyset} \tag{19}$$

Where $\emptyset = a, b, c$ shows the phase from where the current belong to.

The following explanation makes it possible to understand the actual current and the position where the fault and the derivation of the current that occurs. Calculate the fault location of the current and voltage from the end n,

$$U_{f0} = U_{n0}ch(\gamma_0 l_{nf}) - I_{n0}Z_{c0}sh(\gamma_0 l_{nf}) \tag{20}$$
$$U_{f1} = U_{n1}ch(\gamma_1 l_{nf}) - I_{n1}Z_{c1}sh(\gamma_1 l_{nf}) \tag{21}$$
$$U_{f2} = U_{n2}ch(\gamma_1 l_{nf}) - I_{n2}Z_{c1}sh(\gamma_1 l_{nf}) \tag{22}$$
$$I_{f0} = I_{n0}ch(\gamma_0 l_{nf}) - \frac{U_{no}}{Z_{co}}sh(\gamma_0 l_{nf}) \tag{23}$$
$$I_{f1} = I_{n1}ch(\gamma_1 l_{nf}) - \frac{U_{n1}}{Z_{c1}}sh(\gamma_1 l_{nf}) \tag{24}$$
$$I_{f2} = I_{n2}ch(\gamma_1 l_{nf}) - \frac{U_{n2}}{Z_{c2}}sh(\gamma_1 l_{nf}) \tag{25}$$

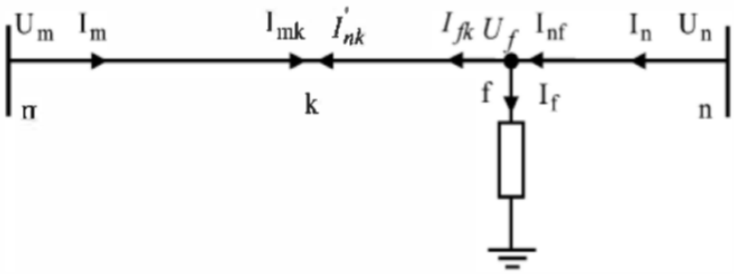

Figure 3. The transmission line modelling was developed with the fault for the existing algorithm

Under ideal measurement conditions, the differential current provides enough information to distinguish between internal faults. Nevertheless, the measurement error due to the CT features of the end of the line, the channel delay measurement, and the limited sampling frequency in the digital relay will cause the relay to measure the false differential current under non-fault conditions.

Hence, the necessity to provide an operating threshold for differential protection. To avoid unnecessarily insensitive protection against low fault currents, most relays have a current-dependent Threshold by using the percentage differential characteristic.

$$I_B = |I_{mk1} + I_{nk1}| \tag{26}$$
$$I_B = |I_{mk1} + I_{nk} - I_{f1}ch(\gamma_1 l_{fk})| \tag{27}$$

4. Power-Line Communications

Power line carrier communication is a method of transmitting information by using existing lines of power and utilizing alternating current in existing lines of power as a means of transmitting information; it is easy to use access points of high-speed networks. There are many communication technologies transfer information, which creates a basic requirement must be fast and economical. One of the technologies that meet the above criteria is PLCC. This technology has been widely used since the 1950s and is mainly used by the network to transmit information at high speed. Today, this technology is widely used in transmission line automation because it avoids the need for additional wiring. Data collected from different sensors is transmitted over these power lines, reducing the cost of maintenance of additional wiring. In some countries, this technology is also used to provide connectivity to the Internet.

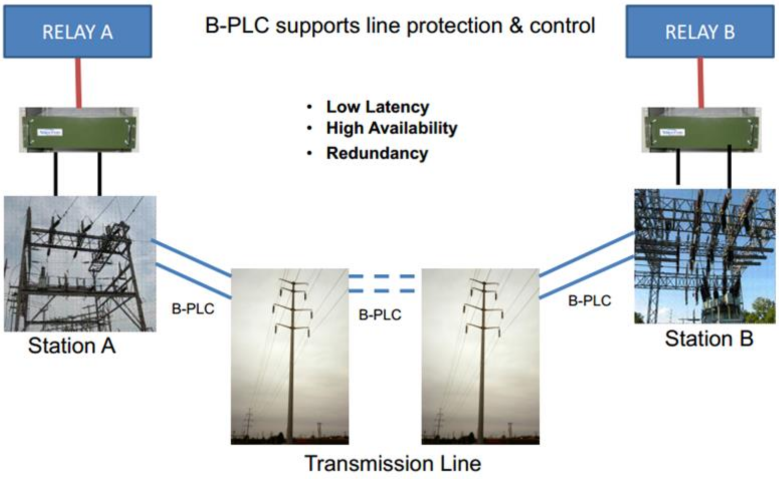

Figure 4A Broadband powerline communications (BPLC)

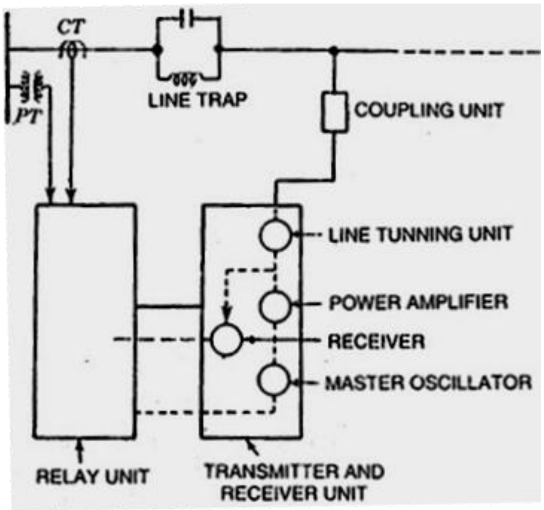

Figure 4B power line carrier communication block diagram

PLCC application

PLCC technology can be implemented for different types of applications to provide cost-effective network solutions. Therefore, merging with other technologies is useful in several fields. These are These are several key areas of communication using PLCC [11],[13]:

1. Transmission & Distribution Network 2. Home Control and Automation 3. Telecommunication
4. Security Systems 5. Automatic Meter Reading

When starting to establish standards and PLC technologies, these standards will define important criteria, such as bandwidth, types of modulation, coding of channels and frequency of work and electromagnetic limits [14], [15].

5. Result and Discussion

The power system comprises two current sensors at both ends of the line consisting 25kV with 100MVA using 5 km transmission line between them. The circuit breaker (3) is installed on the local side, and circuit breaker (4) on the remote side, the Current sensor (A), a current sensor (B) are installed on both sides of the transmission line for measuring the current and voltage of each phase. The current and voltage of each phase of the analog signal is converted to digital data using an analog-to-digital converter (ADC) and then passed to a three-phase differential block.

5.1. Case 1: single line to ground fault (SLGF)

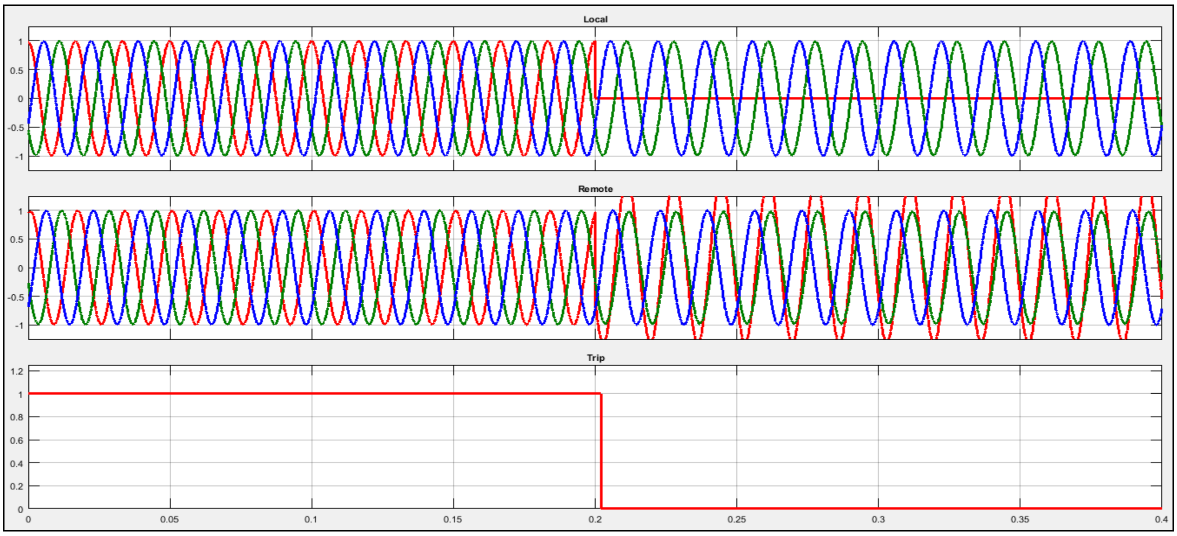

Figure 5. Single line to ground fault currents waveform

The output of the three-phase differential relay module is binary; 1 means the relay is off, 0 means it is activated. When the defect occurs in the protected area, activate the protection process is the difference between the current and the voltage between the two CBs (local and remote). Therefore, when there is a difference in current or voltage at each stage, the relay is set to provide a trip signal. The fault starts at 0.2 milliseconds, the fault occurs to the center of the line as shown in Figure 4. The type of fault is simulated separately. MATLAB R2012a 32 bit, and ode23tb solver configuration parameters used in this simulation. According to different circumstances, the behavior of voltage, current, and the breaker was been studied by simulating the fault at a different location.

5.2. Case 2: Line to line fault (LLF).

The main principle of the differential relay is the protection area of the two ends. By Simulation can be comparing the current for both ends.

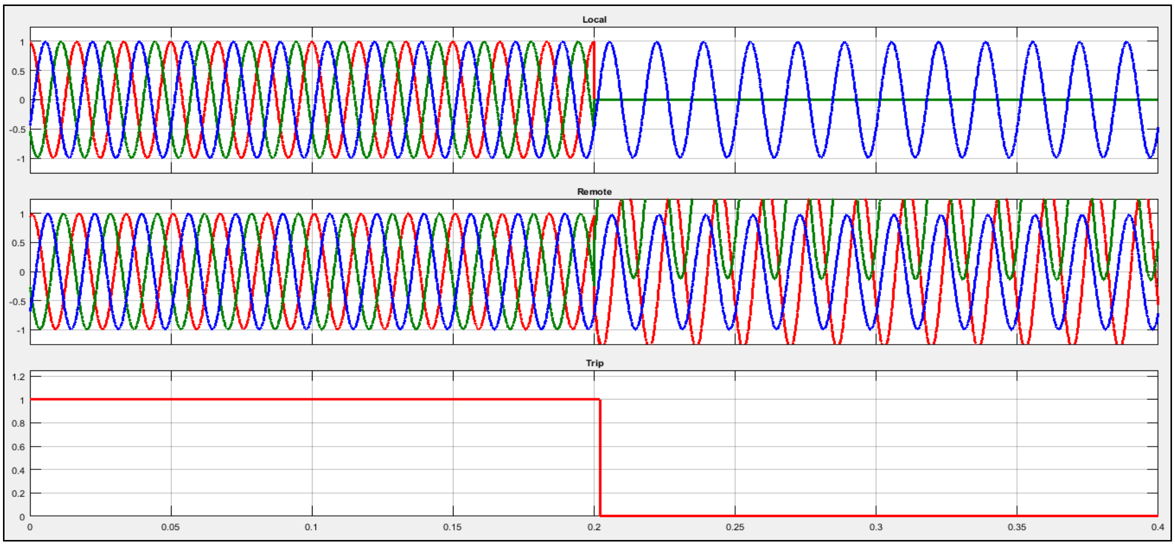

Figure 6. Line to line fault currents waveform

6. Conclusions

Protection of a transmission line is necessary to maintain and improve the stability of a power system. Differential protection is widely used for optimising the fault protection solution, especially in the microgrid and multi-terminal system must be cleared speedily. The differential protection is used popularly; this paper presents a different solution for the protection of the transmission line. This method is better than the protection distance because the differential protection requires less data, such as its input, reduces the calculation time. Furthermore, it covers any fault resistance rating of the lines; in this case, the relay distance is not able to detect internal faults, the proposed method will overcome this problem.

The most significant advantage of the PLC is reliability, ease of installation and cost-effectiveness. The main problem is that international standards (such as FCC in the US and CENELEC in Europe) limit the allowable frequency range of PLC (less than 100 KHz or 500 KHz). Therefore, we cannot use the full potential of the power line for PLC. Given this limited frequency, we cannot always get satisfactory performance from well-known PLC standards. However, the main disadvantage of using PLC in systems is poor performance in high noise environments.

References

[1] Bolandi T G, Seyedi H, Hashemi S M, Nezhad P S 2015 Impedance-Differential Protection: A new approach to transmission line pilot protection *IEEE Trans. Power Del*. **30** 2510-2517.

[2] Abdulwahid A H, Shaorong W 2016 A busbar differential protection based on fuzzy reasoning system and Rogowski-coil current sensor for microgrid *2016 IEEE PES Asia-Pacific Power and Energy Engineering Conference* (APPEEC pp.194 - 199).

[3] Miller H, Burger J, Fischer N, Kasztenny B 2014 Modern line current differential protection solutions Line Current Differential Protection *A Collection of Technical Papers Representing Modern Solutions* pp. 77-102.

[4] Hao Z, Guan J, Chen W, Feng D, Jieqing D, Yidan L, Xiaohui J 2015 Anti-saturation algorithm in differential protection based on the phaselet *5th International Conference on Electrical Utility Deregulation and Restructuring on and Power Technologies (DRPT)*, pp. 1030-1035, 26–29 Nov.

[5] Maofa G, Wenhua X, Xiaoming Z 2013 New method to identify transformer fault with anti-CT saturation based on HHT *Power System Protection and Control* **22** 64-70.

[6] Longfei R, Zhiguo H, Baohui Z 2014 Improved Prony algorithm against transient CT saturation for relay protection *Electric Power Automation Equipment* **34** 126-132.

[7] Louw C, Buque C and Chowdhury C 2014 Modelling and simulation of an adaptive differential current protection scheme for a solar PV microgrid *Renewable Power Generation Conference (RPG 2014)*, 3rd, pp. 1-7.

[8] Seda U E, Okan O, David W 2018 Power line communication channel for smart grid *IEEE 6th International Istanbul Smart Grids and Cities Congress and Fair (ICSG*) April; doi: 10.1109/SGCF.2018.8408974.

[9] Nguyen T V, Petit P, Maufay F, Aillerie M, Charles J P 2013 Powerline communication (PLC) on HVDC bus in a renewable energy system *Energy Procedia* **36** 657-666.

[10] Abdulwahid A H, Shaorong W 2016 A new protection approach for microgrid based upon combined ANFIS with Symmetrical Components *IEEE PES Asia-Pacific Power and Energy Engineering Conference (APPEEC),Xi'an, China*, 25-28 Oct.

[11] Hadlach H T, Mpha Z, Elalami M, Habibi M 2017 Modeling of a Smart Grid Monitoring System using Power Line Communication *International Renewable and Sustainable Energy Conference (IRSEC)*, p.p 1-4.

[12] Ozgonenel O, Thomas D W P, Ercan S U 2017 Power line communication through distribution transformers in smart grid *IEEE 40th International Conference on Telecommunications and Signal Processing (TSP)*.

[13] El Haj Y, Albasha L, El-Hag A, Mir H 2015 Data communication through distribution networks for smart grid applications *IET Sci. Meas. Technol.* **9** 774-781.

[14] Namita N J, Rashmi K B, Reetesh V G 2013 Power line Communication Based on Energy Meter Automation *International Journal of Electronics Communication and Computer Engineering* **4** no. 2.
[15] Papadopoulos T A, Kaloudas C A, Chrysochos A I, Papagiannis G K 2013 Application of narrowband power line communication in medium-voltage smart distribution grids *IEEE Trans. Power Del.* **28** 981-988.

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