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"Detection of Downed or Broken Power Line Fault not Touching the Ground by F-PLCCG"

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Abstract: Occurrences of high impedance faults are common in power distribution between substation to rural area and within rural area. High impedance faults are detected based on fault current measured by fault detection devices but an important fault is the downed or broken power line fault not touching the ground cannot be detected when there is not enough faults current to operate fault detection devices in over head power distribution. Many methods to find high impedance faults exist. However, no proper method exists to find the downed or broken power line fault not touching the ground .Such a condition represents no electrical abnormality and till now its detection would probably have to depend on visual sighting. This is a major safety concern for the public. At present there are no electrical techniques to detect this fault with 100% accuracy with less cost. This study proposes detection of downed or broken power line fault not touching the ground by F-PLCCG. The proposed method is applied to 3-phase system/single phase system and finds the fault in sec.

Key words: Power Line Communication (PLC), PLG (Power Line Guardian), High Impedance Faults (HIF's), Active Smart Wires (ASW), Distributed Series Reactance (DSR), F-PLCCG (Frequency Power Line Carrier Communication Guardian

INTRODUCTION

Power system protection is a critical issue for both operational and safety reasons. An efficient protection scheme should be adapted ensuring the power system operates adequately and protects the equipments as well as public from hazardous over voltages. Hence, an ideal power system protection scheme should be introduced to make sure that no hazardous over voltages will put the human life or equipment operation at risk under any circumstances.

Detection of high impedance faults on overhead distribution systems continues to be an unsolved problem for electric utilities. The root problem is that a high impedance fault does not cause a detectable change in current flow on a circuit. The much more common low impedance faults cause substantial fault current to flow and are easily detectable. Downed conductors are of major concern to electric utilities because they may result in public hazard. Downed conductors may not contact a conductive object and therefore have good probability of remaining energized. When lying on certain surfaces, they may look quite harmless.

A person touching an energized power line conductor faces substantial risk, since, no detection device known today can react fast enough to prevent injury. The only available solution to this problem today is an alert and informed public (Anonymous, 1989a, b). The capability of these new detectors should provide the utility a new tool that can be used to help minimize the public's exposure to downed conductors. It is a tool that should be used with discretion. The issue of how to respond, once a downed conductor (HIF) is detected is paramount. This will often determine whether or not the overall risk to the public has truly been minimized (Anonymous, 1989a, b; O'Brien and Udren, 2015; Cook and Garg, 2013; Hou, 2006; Hou and Fischer, 2005).

Different types of data transmission system can be used depending upon the network requirement and conditions. New PLC communication system are created and used in smart grid (Galli *et al*., 2011; Unsal and Yalcynoz, 2015) to read smart meter data, communication systems and house automation system using power line communication system (Cataliotti and Tine, 2009; Hashiesh and Soukal, 2009). Power line communication is mainly used for detection of high impedance fault occurrence's (Borle *et al*., 2013; Jinde *et al*., 2013).

Smart grid and secure smart grid are being used today to describe technologies that automatically and rapidly isolate faults, restore power, monitor demand and maintain and restore stability for more reliable generation, transmission and delivery of electric power (Popa, 2011; Milioudis *et al*., 2015). Smart grid provide solution for the fault or event and provides electricity free of sags, spikes, disturbances and interruptions. Active Smart Wires

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(ASW) is a new concept for a low-cost, high reliability method to increase or decrease power flow in a transmission line and as well as observe power line between pole to pole every time with (Milioudis *et al*., 2012; Dolezilek and Schweitzer, 2011; Zavoda, 2011; Kreikebaum *et al*., 2010a, b; Das *et al*., 2010).

Downed power lines; Why they can't always be detected: In general OHT (Overhead Transmission), most occurring faults are Short circuit fault and open circuit fault. There are mainly three short-circuit types faults in OHT, Line-Ground (L-G), Line to Line (L-L) and double Line to Ground (LL-G) faults. Line to Ground fault (L-G) is most common fault and 65-70% of faults are of this type (Anonymous, 1989a, b).

Most short circuits involve only normal power carrying conductors. Present technology permits rapid detection and isolation of these short circuits. However, some conductors may fall to the ground onto certain surfaces and not establish a conducting path sufficient to create a full short circuit and some of conductors will not touch ground. At present technology not able to detect this condition and de-energize the circuit. Such cases are a very small portion of the incidents that occur on distribution systems all over the country. But we observe this issue regularly in India.

Causes of downed conductor: I found some of reason in my literature survey for example falling trees or tree limbs are a major cause of downed conductors. Direct lightning strokes to a distribution line may cause insulators to flash over, causing a short circuit to ground of any or all circuit conductors. Such faults may result in downed conductors. Excessive ice loading of circuits can result in mechanical failures, resulting in downed conductors. Vehicle collisions with utility poles can result in downed power lines. Failures of electrical equipment such as insulators or transformers, occasionally cause faults. Such failures usually result in high current but seldom in a downed conductor. Aged transmission lines conductors resulting in downed conductors (Anonymous, 1989a, b). For example, recent incidents in India: vehicle top touched power conductor lines, downed power lines on humans because of power line patches broken, aged lines, etc.

Characteristics of downed power lines and so far used methods: Detection of high impedance faults like downed power line fault not touching ground on OHT continues to be an unsolved problem for electric utilities. The root problem is that a high impedance fault does not cause a detectable change in current flow in a circuit. The much more common low impedance faults cause substantial fault current to flow and are easily detectable (Anonymous, 1989a, b; O'Brien and Udren, 2015). At present, there are no electrical techniques envisioned that can detect downed or broken power line fault not touching the ground. Such a condition represents no electrical abnormality and its detection would probably have to depend on visual sighting.

The current in some high impedance faults has a distinctive quality different from load current. A technique called "Pattern recognition" can be used to identify these differences. Earlier attempts to use this technique experienced difficulty in detecting some types of high impedance faults. Such detectors also had a security problem. This approach is in need of further research to improve its reliability and effectiveness (Anonymous, 1989a, b; O'Brien and Udren, 2015).

Downed conductors are of major concern to electric utilities because they may result in public involvement in a hazardous situation. Downed conductors may not contact a conductive object and therefore have good probability of remaining energized. When lying on certain surfaces, they may look quite harmless. A person touching an energized power line conductor faces substantial risk, since, no fault detection device known today can react fast enough to prevent injury. The only available solution to this problem today is an alert and informed public (Cook and Garg, 2013; Hou, 2006; Hou and Fischer, 2005).

Principle of Power Line Communication (PLC): PLC technology is used for data communication in medium and low voltage power lines. It uses the power lines and provides high data transmission in short filed (Galli *et al*., 2011; Unsal and Yalcynoz, 2015), so, it is suitable for using in HAN (Home Area Network) and NAN (Neighborhood Area Network).

MATERIALS AND METHODS

Working principle of power line communication: Figure 1 block diagram shows a brief overview of power line communication. The analog/digital data is converted to its analog counterpart using FSK modulation. FSK modulated signal is stepped up and then sent to the AC power lines via. the coupling circuitry. At the receiver end, the signal is first stepped down and then filtered in order to remove the unwanted noise elements. The modulated data is demodulated at the FSK demodulator.

Operation of PLC: The system mentioned above (Fig. 1) is compatible with both analog as well as digital data. PLC having controller. Controller is to do facilitate error detection and correction. The data is forwarded to the modulator. Modulation is the process of translating low frequency baseband signal to high frequency high band pass signal. The need for modulation here is to mainly trans form digital signal into equivalent analog signal using a form of modulation known as Frequency Shift

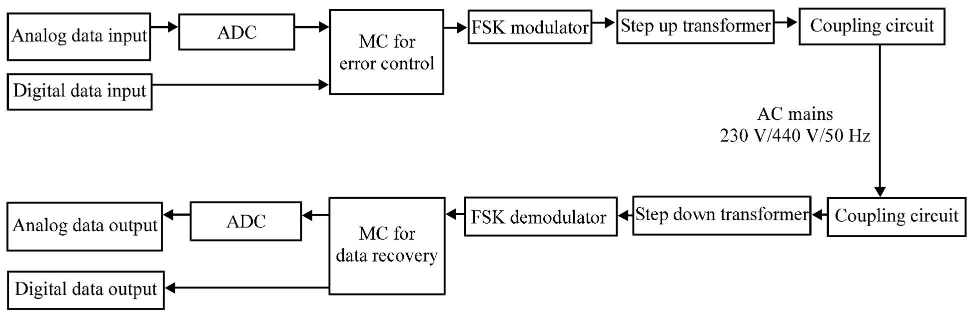


Fig. 1: General architecture of the PLC system

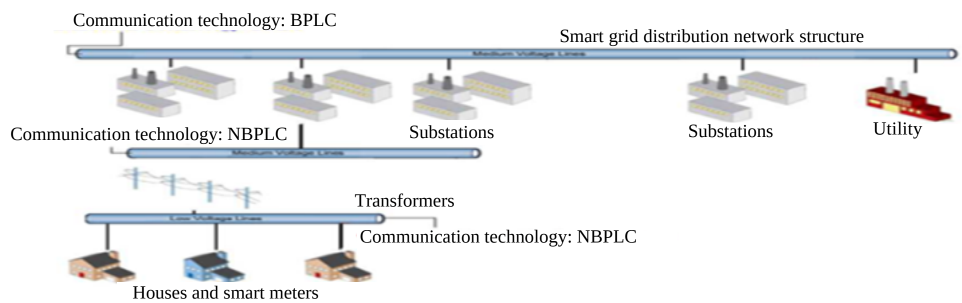


Fig. 2: Smart grid distribution network architecture

Keying (FSK) and also, to translate it to a higher range of specially selected frequencies, so as to keep the data safe from noise interferences. The output of the FSK modulator is a signal of amplitude between 5-10 V.

In PLC, Power system and the communication system operate at the two extremes power system at very low frequency and very high power, current and voltages levels and communication systems at much higher frequencies and very low power, current and voltage levels. To be able to design PLC systems as well as to supply a proper interface between power and communication system the coupling circuitry is must.

After the data has traveled all the way and reached the destination the next important thing is to accept this combined (50 Hz+FSK signal) signal through a coupling circuitry. The received will be at 230 V, therefore, we need to step down it before proceeding.

The band of frequencies chosen for the band pass filter is from (86-103k). This range eliminates two things. It rejects the 50 Hz power lines signal as well the noise from the high frequency range (above 200 kHz). The modulated data is demodulated at the FSK demodulator.

In t he above diagram Fig. 2, it is shown how a BPLC and NBPLC technologies are used in different length of transmission lines (Galli *et al*., 2011; Cataliotti and Tine, 2009). At present days power line communication used for measuring smart meter reading, detection of power theft between pole in smart grid (Hashiesh and Soukal, 2009; Borle *et al*., 2013; Jinde *et al*., 2013; Popa, 2011; Milioudis *et al*., 2015).

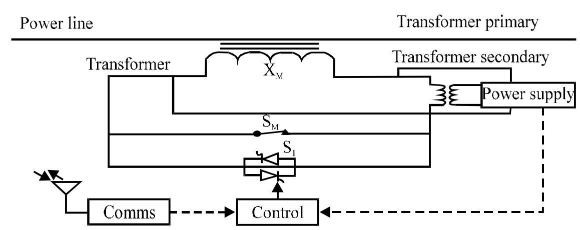


Fig. 3: Schematic diagram of Power Line Guardians ("PLG")

Power Line Guardians ("PLG"): Electrical transmission and distribution system is using new technologies and methods for dynamic power flow control. One of the important technologies is Power Line Guardian's (PLG's). The PLG's are mounted directly on the conductors. The operating power for PLG is drawn from the conductor and PLG connected in series with the transmission line. The PLG system consists of hardware and software components. Hardware is used for the impedance change on overhead line and software is used for controlling the power flow.

Figure 3 shows the schematic diagram of PLG. The PLG is a transformer and conductor used as primary

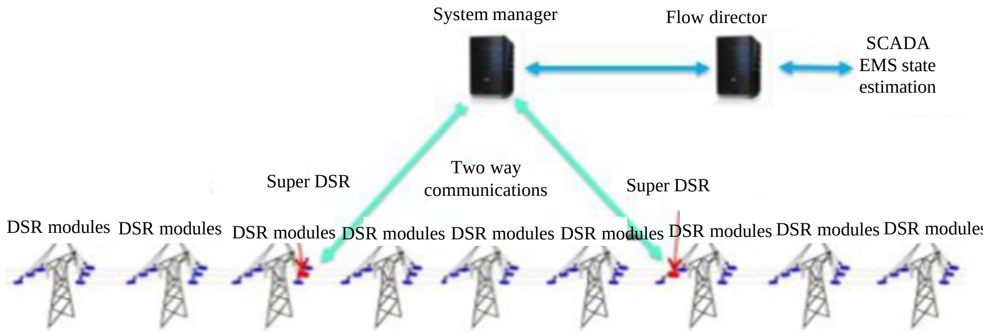


Fig. 4: The PLG communications system

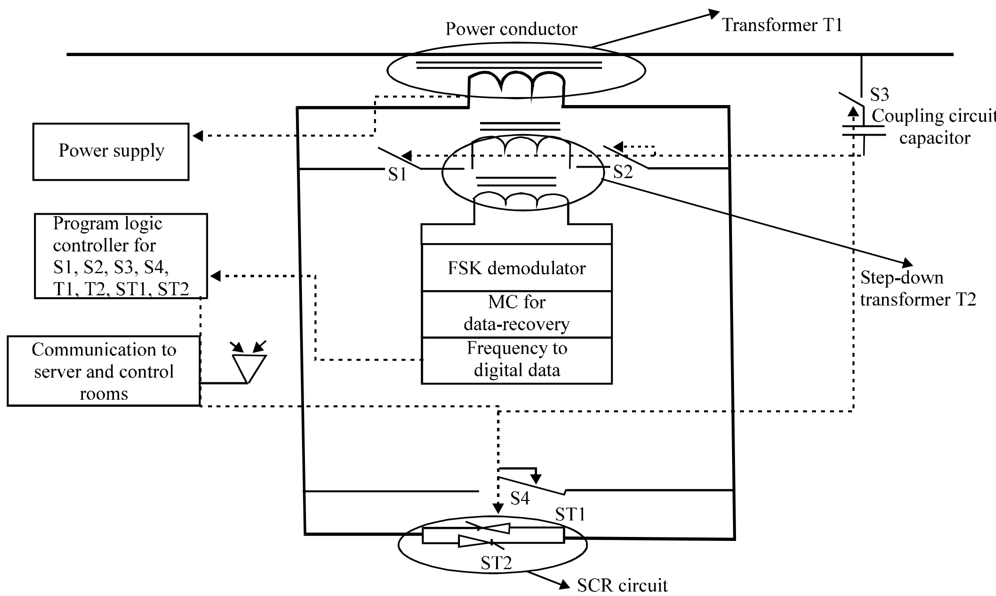


Fig. 5: F-PLCCG schematic circuit

winding of transformer. PLG can control the level of current or temperature of conductor or line impedance by using switch operation.

PLGs are also, used to provide the real time data on the lines such as: line current, conductor temperature, frequency, sag and blowout angles (Milioudis *et al*., 2012; Dolezilek and Schweitzer, 2011; Zavoda, 2011; Kreikebaum *et al*., 2010a, b).

The diagram (Fig. 4) shows the PLG communications system. PLGs (blue) control the power flows on the lines. Super PLGs (red) can control both the power flows and the PLGs. These super PLGs are also, used to communicate with Energy Management Systems (EMS) and allow the automatic control of PLGs (Das *et al*., 2010; Kreikebaum, 2010a, b). Limitations of Power Line Guardians ("PLG"): the retail price of smart wires is $1000 per 10 kVA module (Kreikebaum *et al*., 2010a, b).

Design, working principal and operation of F-PLCCG; (Frequency Power Line Carrier-Communication Guardian): The proposed design of F-PLCCG is used for detection of unbroken/broken conductor hanging within inches from the ground fault or downed power line conductors fault between two sub-stations and within village (Fig. 4 and 5) the design and operation of F-PLCCG is explained as:

Design of F-PLCCG (Components): The F-PLCC contains components like Transformer (T1), Transformer (T2), Switches S1-S3, power supply, program logic controller (S7-1200) with GSM connection, communication system, FSK demodulator, micro controller for data recovery, digital data converter, SCR (Silicon Controller Rectifier) circuit (ST1, ST2) and coupling circuit capacitor and components working explained in Fig. 5.

- Transformer (T1) of primary act as a power conductor
- Transformer (T1) of secondary act as a primary of T2
- If switch S4 closed, combination of switch S4 and SCR's ST1 and ST2 act as a power line guardian circuit
- Coupling capacitor for allowing high frequency signals to F-PLCCG
- S7-1200 (contains pre program) and communication system will receive power supply from Transformer (T1)
- FSK demodulator: frequency shift key demodulator used for decrease carrier signal frequency received from T2 secondary
- Communication system having GSM modem for sending data to substations or rural transformer switch board

Working principle and operation of F-PLCCG: F-PLCCG is following basic principle of power line communication system. Please follow below steps how it will detect downed power line conductors fault between two sub stations.

Step 1: Once program logic controller signal received from substation "A", Switches S1-3 will closed by using program logic controller (at F-PLCCG).

Step 2: Coupling circuit capacitor will allow high frequency signal, step down transformer T2 step-down voltage signal.

Step 3: Step-downed voltage signal send to FSK demodulator it will demodulated frequency to low frequency signal.

Step 4: MC (Micro Controller) correct the error in low modulated frequency signal.

Step 5: Frequency convert into digital signal and send digital value to programmable logic controller.

Step 6: Program logic controller will check frequency value and send signal to communication system "OK" or "NOK" (pre program logic written in Ladder logic, explained as).

Step 7: Depends upon signal received from communication system in F-PLCCG, send signal to substations for switch off power supply between two sub stations or switch off power supply to rural area.

Programmable logic: Program logic controller logic for operation of switches in F-PLCCG (please find logic of operation in Fig. 6).

Detection of unbroken/broken conductor hanging within inches of the ground fault or downed power line conductors fault using F-PLCCG Field operation and algorithms: According to literature survey one major problem has identified. Problem is downed conductors which are not touching the ground has become major concern to electric utilities because this fault cannot be measured by the fault detecting devices. This may result in public harm. Downed conductors may not contact a conductive object, therefore is more probability of remaining energized.

When lying on certain surfaces, they may look quite harmless. When any person touches an energized power line conductor, faces substantial risk, since, no detection device known today can react fast enough to prevent injury. In recent years observed that many cases were registered in so many countries like India, USA, Germany, etc. The only available solution to this problem today is to give an alert and inform public. To solve above problem companies like siemens, GE, ABB, etc. have a solution but that solution has only 90% success rate.

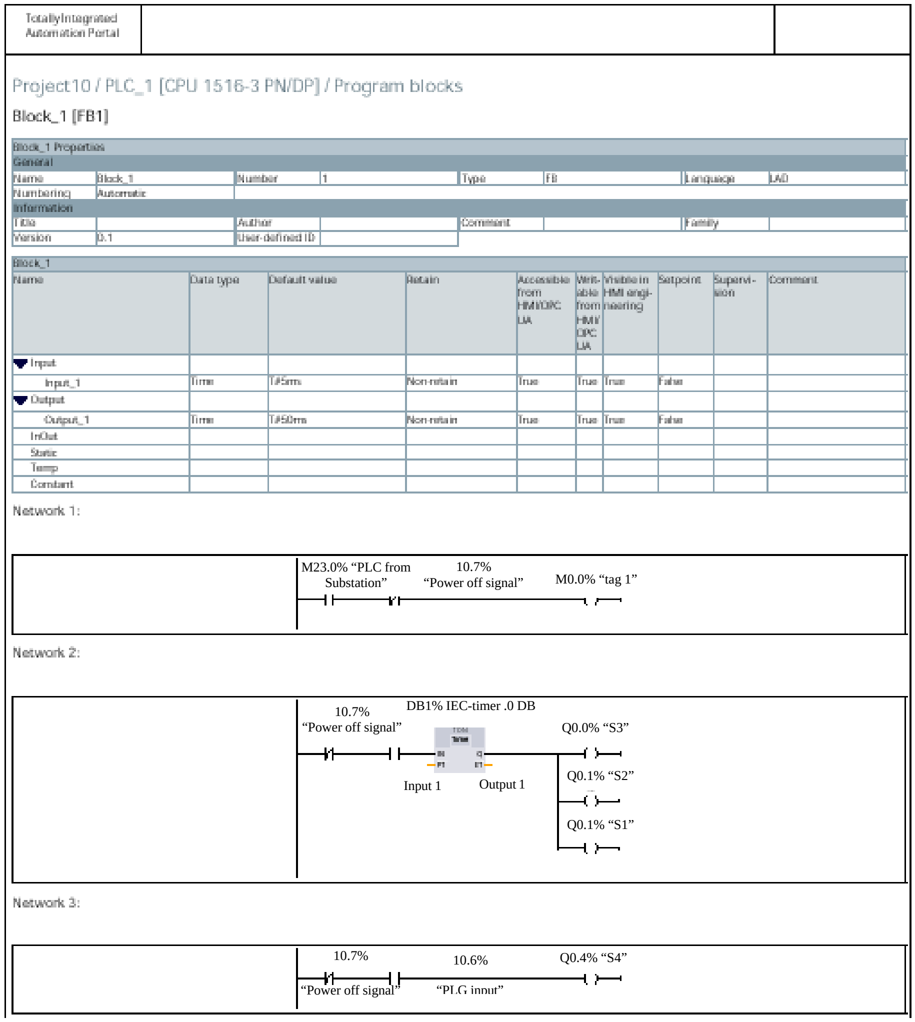
To solve above problem proposing new enhanced model circuit. It contains F-PLCCG, program logic controller (Siemens PLC CPU-1200) for logic function operated in F-PLCCG. The proposed solution unique approach towards solving problem compared to other proposed solutions.

The proposed solution explains how to deal with unbroken/broken conductor hanging within inches of the ground fault or downed power line conductors fault. Here, explaining how to use proposed solution in between two sub-stations and as well as with in rural village. Proposed solution solves fault detection between substation to substation is explained in:

- Flow chart 1 using some preconditions (Fig. 7)
- Algorithm steps (F-PLCCG working in field)
- Field connection diagram of F-PLCCG (Fig. 8)

And this solution also solves fault detection between substations to rural village explained in:

- Flow chart 1 using some preconditions (Fig. 9)
- Algorithm steps (F-PLCCG working in field)
- Field connection diagram of F-PLCCG (Fig. 10)


TotallyIntegrated Automation Portal

Project10 / PLC_1 [CPU 1516-3 PN/DP] / Program blocks

Block_1 [FB1]

Block_1 Properties							
General							
Name	Block_1	Number	1	Type	FB	Language	LAD
Numbering	Automatic						
Information							
Title		Author		Comment		Family	
Version	0.1	User-defined ID					

Name	Data type	Default value	Retain	Accessible from HMI/OPC UA	Writ-able from HMI/OPC UA	Visible in HMI engi-neering	Setpoint	Supervi-sion	Comment
Input									
Input_1	Time	T#5ms	Non-retain	True	True	True	False		
Output									
Output_1	Time	T#50ms	Non-retain	True	True	True	False		
InOut									
Static									
Temp									
Constant									

Network 1:

Network 2:

Network 3:

Fig. 6: Program logic controller logic

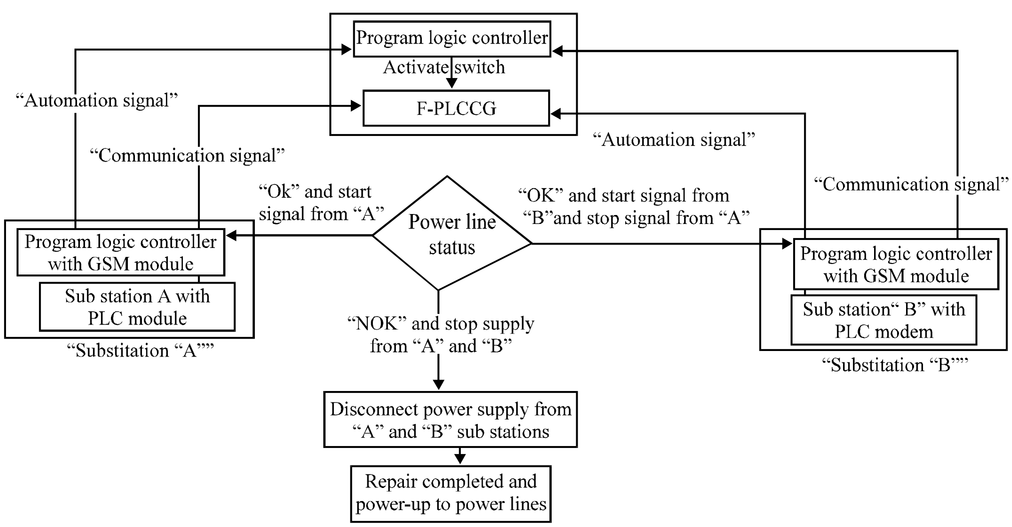


Fig. 7: Flow chart: F-PLCCG operation between substations to substation

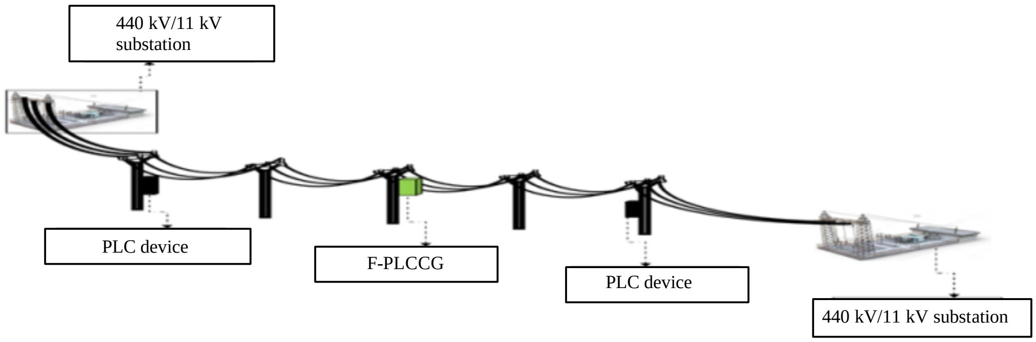


Fig. 8: F-PLCCG field connection between substation to substation

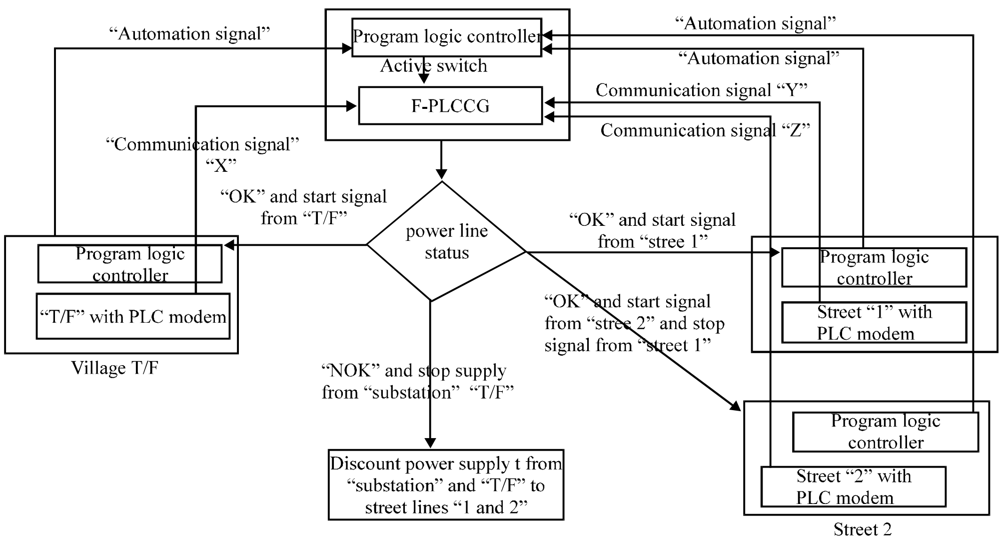


Fig. 9: Flow chart: F-PLCCG operation between substations to village

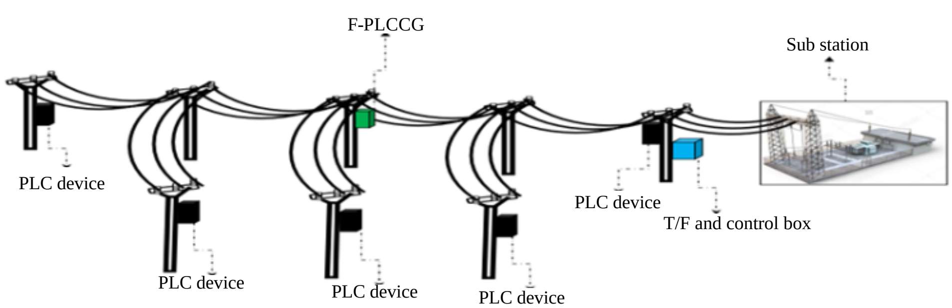


Fig. 10: F-PLCCG Field connection between substations to village

Precondition algorithm:

Step 1: At equal distance between sub-station "A" and "B", arrange F-PLCCG

Step 2: F-PLCCG (Frequency Power Line Carrier Communication Guardian) has frequency receiver in bi-directional mode

Step 3: Preferred frequency for PLC (Power Line Carrier) is 100-140 kHz

Step 4: Sub-station "A" and "B" contains PLC modem and program logic controller (Pre-program) unit with GSM connection

Step 5: For better understanding of algorithms, we symbolize power line communication signal as communication signal and program logic controller signal as automation signal.

Algorithms steps (Fig. 7):

Step 1: Sub-station "A" PLC modem will send "Communication signal" to "F-PLCCG" v0ia. transmission line and as soon as signal passes from PLC modem, program logic controller (at substation) sends "Automation signal" to program logic controller (at F-PLCCG) for activation of switches Fig .6

Step 2: Once the communication signal signals reached “F-PLCCG”, status of the transmission line is sent to two sub-stations via. communication system arranged in “F-PLCCG”

Step 3: F-PLCCG sends only “OK” or “NOK” signal to two substations. If F-PLCCG signal status is “OK” it will execute as in step 4, if “NOK” then it will execute as in step 6 and 7

Step 4: Stop communication signal from substation “A” and from substation “B” send communication signal to “F-PLCCG” and when signal passes from PLC modem, program logic controller sends automation signal to F-PLCCG for activation of switches (Fig. 6)

Step 5: Once communication signal reaches “F-PLCCG”, status of transmission line send to two sub-stations via. communication system arranged in “F-PLCCG” and F-PLCCG send only “OK” or “NOK” signal to two substations. If F-PLCCG status is “OK” it will execute as in step 1, if it’s “NOK” it will execute as in step 6 and 7

Step 6: Communication signal not reached “F-PLCCG “ it will generate “NOK” signal i.e., transmission line broken and sent this automation signal to substations “A” and “B” and generates alarm for disconnect power supply from both “A” and “B” substation or automatic disconnection of power supply by SCADA system in both “A” and “B” substation

Step 7: Once the line repair is executed, then operator has to press ready button then controller start power supply to village and it will execute as in step 1

Precondition for flow chart 2

Step 1: F-PLCCG connected at every power distribution node for streets.

Step 2: Connect PLC device at transformer (in rural area) and transformer power connection switch on/switch off operation using by pre-programmable logic controller (Control box).

Step 3: Each street end at the last electric transmission pole is connected to PLC device and village T/F (transformer) having PLC modem and when communication signal passes from PLC modem of T/F, program logic controller (located at street end last electric transmission pole) it sends automation signal to program logic controller (at F-PLCCG) for activation of switches (Fig. 6).

Step 4: Preferred frequency for PLC (Power Line Carrier) is 100-140 kHz.

Step 5: In village/rural area each home contains smart meter and each smart meter contains wave trap unit.

Step 6: For better understanding of algorithms, we symbolize power line communication signal as communication signal and program logic controller signal as automation signal.

Algorithms steps; T/F PLC modern:

Step 1: T/F PLC modem will send communication signal “X” to F-PLCCG via. transmission line

Step 2: F-PLCCG receives “X” signal and status of transmission line send to sub-station “A” and control box at T/F (transformer) via. communication system arranged in “F-PLCCG”. F-PLCCG sends only “OK” or “NOK” signal to substations. If F-PLCCG status is “OK” it will execute as in step 3, if it’s “NOK” it will execute as in step 5

Step 3: Stop “X” signal from transformer PLC. F-.PLCCG receives communication signal “Y” from street 1 of PLC modem and status of transmission line send to Sub-station “A” and control box at T/F (Transformer) via. communication system arranged in “F-PLCCG” and F-PLCCG sends only “OK” or “NOK” signal to sub stations. If F-PLCCG status is “OK” it will execute as in step 4, if it’s “NOK” it will execute as in step 5

Step 4: Stop “Y” signal from street 1.F-PLCCG receives communication signal “Z” from street 2 of PLC modem and status of transmission line send to sub-station “A” and control box at T/F (Transformer) Via. communication system arranged in “F-PLCCG” and F-PLCCG sends only “OK” or “NOK” signal to substations. If F-PLCCG status is “OK” it will execute as in step 5, if it’s “NOK” it will execute as in step 5

Step 5: If F-PLCCG generated “NOK” signal and send automation signal to within rural village transformer and substation. Transformer control box having program logic controller loaded with preprogram with all these conditions, once received “NOK” signal from F-PLCCG controller will disconnect power supply to village. Once line repair executed then operator has to press ready button in control box, after controller start power supply to village and it will execute as in step 1

RESULTS AND DISCUSSION

Simulation results: We used MATLAB for this simulation results. Inputs for simulation results: from substation “A”: power line communication with frequency 1 kHz, normal power supply 440 V_{AC}, 50 Hz. Output measured across secondary of T2.

The output signal of T2 is input for FSK, FSK output is input for frequency to digital conversion. At final input signal frequency of communication signal at station “A” = output signal frequency at F-PLCCG. So, it indicates down conductor fault not occurred (Fig. 11).

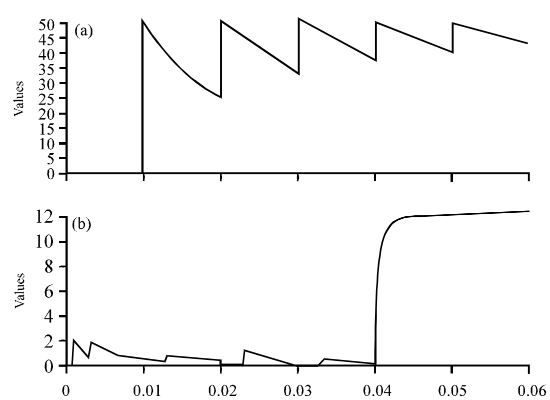


Fig. 11: Output frequency across transformer T2 secondary: a) Frequency signal of source V and b) Frequency signal of carier signal obtained at T/F

CONCLUSION

In smart grid as of now very few methods for finding downed power lines fault without touching ground. As compare to all of that's methods and process, the proposed solution will give better solution, economic and with in less time. I hope it will give almost 100% accurate solution for detect downed power lines fault without touching ground. This study provides solution used for rural area/village and between two substations. Further research work will be F-PLCCG used for power line communication booster and detection of fault location.

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