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Case Study: Performance of Power Line Communications under various loads conditions

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The widespread and availability of electrical network, attracts the attention of engineers to use this vast network as communication media to transmit and receive data over 50 Hz or 60Hz power line, this technology is known Power Line Communications. This technology enables the two-ways communications which will helps in effective monitoring and controlling of grid resources makes our electrical gird into smart electrical grid. This paper reports the performance of Power Line Communications under various conditions such as type of electrical and electronics appliances, distance between PLC transmitter and receiver, distance from appliance to PLC receiver, frequency of operation etc. Experimental setup is made using server-client communication where DLMS Energy meter simulator acts as client and DLMS Explorer as server.

Keywords: *Broadband-Power Line Communication, Switching Noise, Electromagnetic Interference, Switch Mode Power Supply(SMPS).*

1.0 INTRODUCTION

Our existing electrical grid uses power-line/cables to transmit electrical power from generation unit to distribution network and furthers from distribution side to end-users at 50 Hz or 60 Hz frequency. Due to its vast & widespread network this can also be used as medium of communications that will reduce the cost of installation by not deploying additional cable for the communication. This technology is known as Power Line Communications or Power Line Carrier Communications.

This technology finds major applications in the area of home automation where smart home appliances are connected and control by remote location, Internet connectivity using Home Area Network and also uses by electrical utilities for Advanced Metering Infrastructure (AMI) for billing, load management during peak-hours, apart from automatic billing this technology provides value added services to customers such as notification tariff plan during peak hours, pattern of power consumption on daily bases, remote disconnection when customer not available and many more.

Since these power line or cables are designed for carrying electrical energy at 50 Hz or 60 Hz when a high frequency signal (from few kilo Hz to hundreds Mega Hz)on these lines, PLC signal suffers frequency-selective fading, attenuation, signal loss due to multiple reflection cause by number of branches in electrical network [1-4]. Hence these factors make communication over power-line as a harsh medium for communications purpose.

Expression (1) provides attenuation factor at high frequency given by skin effect from high frequency transmission line model [5]

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$$R\_f=R\_dc*k*\sqrt{f} \quad \ldots(1)$$

Where,

R_f = Attenuation of wire at high frequency,

R_{dc} = Attenuation of wire at low frequency (near to DC),

k = Wire gage factor,

f = Operating frequency of signal.

Power Line Communications is further characterized into two categories based on operating frequency I). Broadband-Power Line Communication (B-PLC) II). Narrowband Power Line Communication (NB-PLC) [4] as listed in Table 1.

TABLE 1
COMPARISON OF BROADBAND AND NARROW POWER LINE COMMUNICATIONS.

Sl. No.	Narrowband PLC		Broadband PLC
1	Operating frequency	Up to 500 kHz (In Europe from 3kHz -148.5 kHz and in USA from 155kHz -490 kHz)	Over 2 MHz (2-250 MHz)
2	Data transmission rate	Up to 100 kbps	Over 1 Mbps
3	Modulation	SFSK, BPSK, OFDM	OFDM
4	Applications	Building automation, Smart grid, AMI	HDTV, Internet, IP based security camera

2.0 EXPERIMENTAL SETUP

Experimental setup is completed to study the performance of Power Line Communications under various loads conditions using the following equipments and systematic diagram as shown in Figure 1.

Head-End Unit is responsible for transmitting the information signal into high frequency OFDM (Orthogonal Frequency Division Multiplexing) signal. In our experiment Broadband-Power Line Communications is used which is operating from 2 MHz to 12 MHz and signal having strength of 85 dBμV to 95 dBμV and number of carriers are 1536.

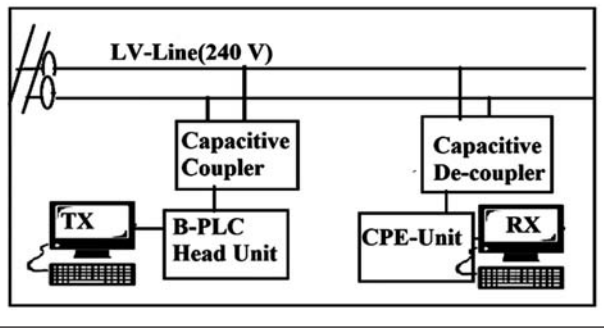

FIG.1 SYSTEMATIC LAYOUT OF EXPERIMENTAL SETUP

Capacitive Coupler Unit is responsible for injecting the high frequency PLC signal into power-line of 50 Hz or 60 Hz. It is basically high pass filter to pass PLC signal and also provides protection against voltage surge.

De-coupler Unit is responsible for extracting back PLC signal from the power-line, it does the reverse operation of coupler.

Consumer Premises Equipment unit is responsible for converting back PLC signal into original transmitted signal by performing the reverse operation of Head-End unit.

Network Management System (NMS) is CPU of PLC network which is responsible for managing and controlling the various equipment such as Head-end unit and Consumer PremisesUnit (CPE) by configuring these unit by IP address.

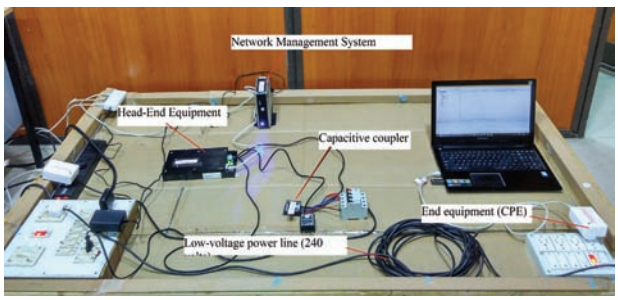

FIG. 2 EXPERIMENTAL SETUP OF POWERLINE -COMMUNICATIONS

To study the performance of PLC communications is tested using server-client communication where the DLMS Energy Meter Simulator acts as client and DLMS Explorer (tool to read energy meter simulator) acts server which are running on two different PC. Figure 2 shows the experiential setup made the CPRI premises.

3.0 CASE STUDY

To evaluate the performance of PowerLine Communications under various condition, many electrical and electronics appliances are connected to the same power-line where PLC communication is happening. As addition load/ appliances may also be present on same line isolation transformer is used to suppressed their effect and it is assumed to be very less on PLC. Initially PLC Communication is tested between server-client without any appliance connected to power-line, data transmission is successful and communication status is checked using the ping command. Figure 3 & 4 shows communications between server-client with data transmission successful status.

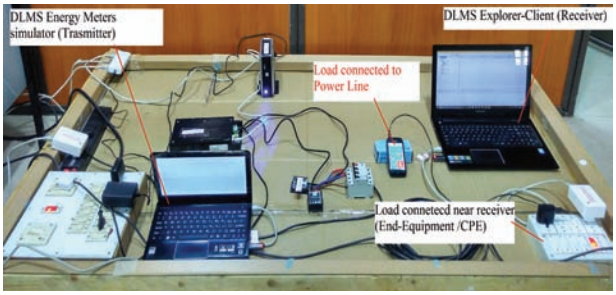

FIG.3 SERVER-CLIENT COMMUNICATION ON 240 V LINE

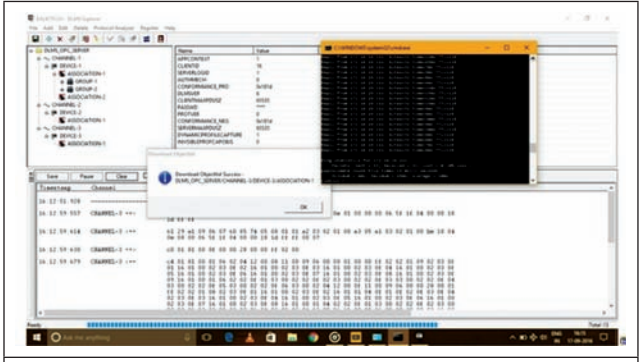

FIG.4 DATA TRANSMISSION STATUS

The same experimental setup of PowerLine Communications is tested under various conditions such as with various type of electrical and electronics appliances connected to the same power line as listed in Table 2.

When Table-fan is connected as a load shown in the Figure 5 and the performance of PLC communications is slightly affected but the data transmission is successful between two PC with slightly delay in data transmission time. As table fan have induction motor which will introduce Electromagnetic Interference (EMI) of low strength to Power Line Communications [6].

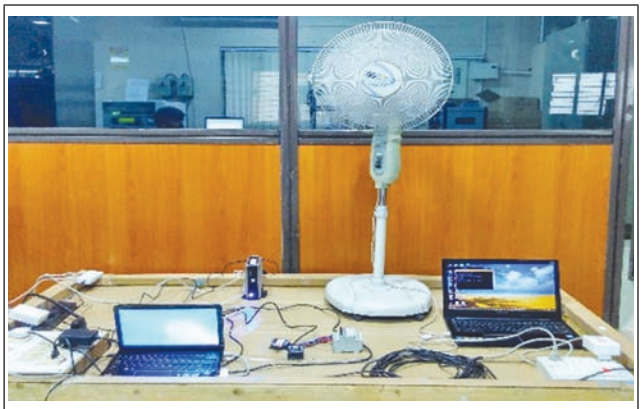

FIG.5 FAN AS LOADS TO POWERLINE COMMUNICATIONS

When Phone adaptor is connected as load, there is increase in data transmission delay in some cases it is observed that timeout error. As these devices employs non-linear device such as Silicon Controlled Rectifiers (SCR)/Diodes which introduces IGBT noise to power-line and effects the communications as shown in the Figure 6 & 7.

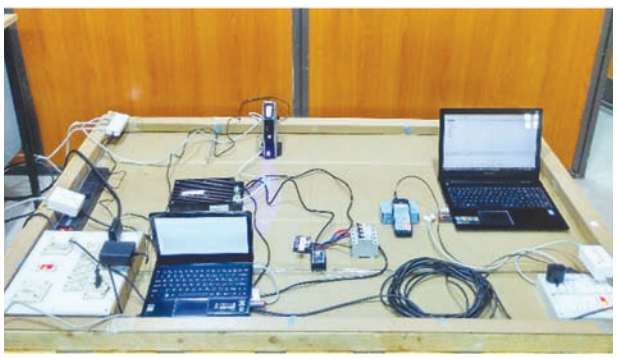

FIG. 6 PHONE ADAPTOR AS LOADS TO POWERLINE COMMUNICATIONS

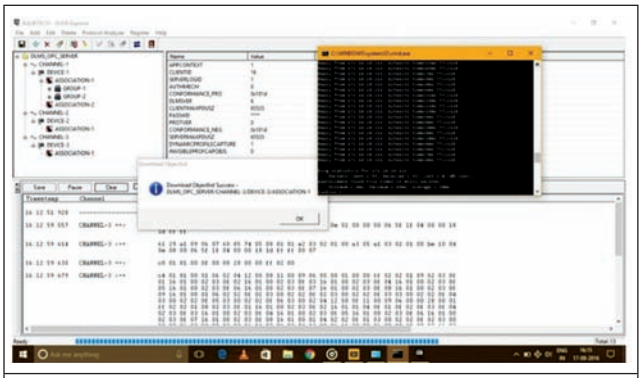

FIG. 7 DATA TRANSMISSION STATUS

When Fluorescent Light lampis connected as a load as shown in Figure 8. The data transmission got failed but sometimes successful with long delay. As these loads generates harmonics of high frequency that sometimes of same operating frequency of PLC signal and cause interference to communications [7].

When Personal Computer is connected as a load, data transmission got affected withlong transmission delay as computer employs power assembler or SMPS (Switching Mode Power Supply) which introduces higher strength Electromagnetic Interference (EMI) to communications signal [8] as shown in Figure 9.

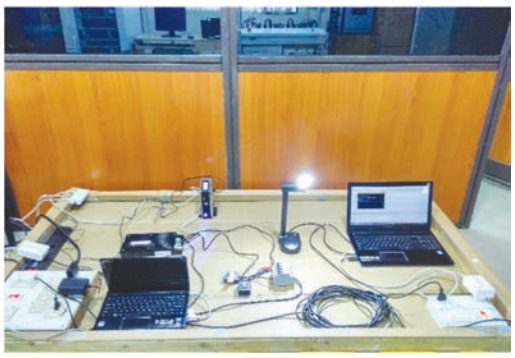

FIG. 8 FLUORESCENT LIGHT LAMP AS LOADS TO POWERLINE COMMUNICATIONS

TABLE 2

VARIOUS LOADS CONNECTED TO POWERLINE COMMUNICATION SETUP

Sl. No.	Loads connected	Distance between client and load (metres)	Connection status & observed transmission delay (milliseconds) with Load	Connection status & observed transmission delay (milliseconds) without Load
1	No-Load	-	-	Successful Duration =4 ms
2	Table-Fan	2 m	Successful Duration =36 ms	Successful Duration =4 ms
3	Phone Adaptor	1.5 m	Successful Duration =162 ms	Successful Duration =4 ms
4	Fluoresce-nt Light Lamp	1m	Fail/sometimes successful Duration=977 ms	Successful Duration =19 ms
5	Personal Computer	2 m	Fail Duration=1365 ms	Successful Duration =19 ms
6	Drilling Machine	1.5 m	Fail Duration=262 ms	Successful Duration =3 ms
7	UPS/ Invertor	2 m	Successful Duration=18 ms	Successful Duration =4 ms
8	With all loads from sr. no 1 to 7.	Within 2-3 m	Fail Duration=3653 ms	-

When a Drilling Machine is connected as load, communications are severely affected with data transmission failed every time. As drilling machine employs universal motor which generates strong Electromagnetic Interference (EMI) to PowerLine Communications [9]. Figure 10 & 11 shows Drilling machine and data transmission failed status.

When a Uninterruptible Power Supply (UPS)/ Invertor is connected as a load shown in Figure 12, communication got affected but successful with delay in data case which introduces switching noise to PLC communications[8].

FIG.9 PERSONAL COMPUTER AS LOADS TO POWERLINE COMMUNICATIONS

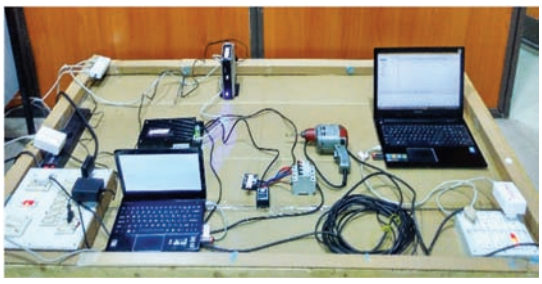

FIG.10 DRILLING MACHINE AS LOADS TO POWERLINE COMMUNICATIONS

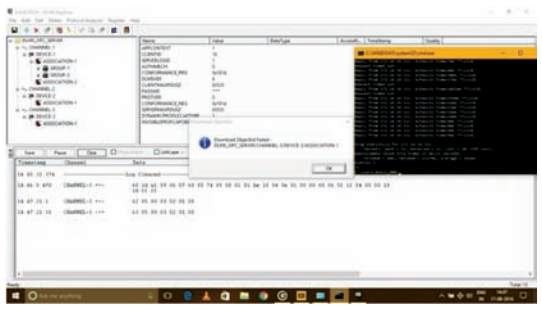

FIG. 11 DATA TRANSMISSION STATUS

FIG. 12 UPS/INVERTOR AS LOADS TO POWERLINE COMMUNICATIONS

4.0 DISCUSSION

It has been observed that under various loads conditions the performance of Power Line Communications is severely affected due to the interference introduces by these appliances to Power Line Communications. It is also observed that loads which are place far from PLC receiver & transmitter have less effect on PowerLine Communications. Table 3 listsper formance of Power Line communications when the distance between load and PLC transmitter is varied.

TABLE 3
LOADS CONNECTED TO PLC SETUP UNDER WIDE RANGE OF DISTANCE

Sl No.	Loads	Distance between Tx and load (metres)	Connection status	Transmission time (milliseconds)
1	Old computer	2 m	Fail	1365 ms
		4 m	Fail	996 ms
		12 m	Successful with delay	300 ms
2	Drilling machine	2 m	Fail	1554 ms
		4 m	Fail	1121 ms
		12 m	Fail	915 ms
3	With all loads from sr. no 1 to 8 from table II	2 m	Fail	3653 ms
		4 m	Fail	3415 ms
		12 m	Fail	3215 ms

Figure 13 shows signal to noise ratio(SNR) graph of PowerLine Communications in the frequency range of 2 MHz to 12 MHz with signal strength of 50dB which is obtained from Network Management System (NMS).

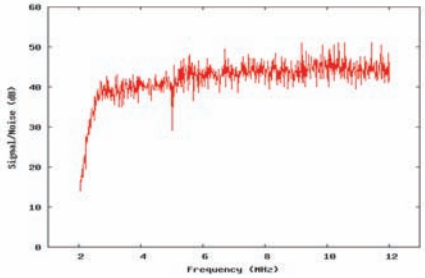

FIG.13 SIGNAL TO NOISE RATIO GRAPH

5.0 CONCLUSIONS

It has been observed that noise coming from various electrical & electronics appliances will affects the communications performance and detailed study of these noise is carried out by authors in the paper[10].

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