Impact and Control Study of LV Communication Networks with PV Penetrated Micro Grid

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Abstract - *In recent years, consumer demand, energy consumption rates, also control and communication requirements have increased. The result of it, controlling of the electrical system is getting more difficult day by day. The importance of communication also has increased in direct proportion with the control. So, the systems need remotely control and communication system by advanced technologies with distributed energy resources. It means that, transforming the existing electrical grid into the smart grid requires remote control for the development of communication and control system. It provides more efficient, more convenient and more reliable systems and its structures are being researched in this study. Communication structures used in control requirements and integration of renewable electrical sources are studied. Then, new smart micro grid system model is designed which is used with power line communication infrastructure. It contains distributed energy resources; electric vehicles system and the overall system is simulated by Matlab. Photovoltaics technology is integrated as distributed resources and the simulation results are examined for the quality of transmitted energy in different situations of the micro grid.*

Key Words: Micro Grid, Control, Communication, Photovoltaics, Efficiency

1. INTRODUCTION

The Smart Grid (SG) is an idea of achieving a more effective system with improved demand-side management on effective communication technology and efficiency. This idea targets transmitting electricity with high efficiency and has a very large field of interest such as communications, control systems, and semiconductor technology.

The major aim of the advanced SG concept can be categorized in three subjects: increasing the utilization of Distributed Energy Resources (DER) and Demand Response (DR), better asset utilization, and enhanced customer choice [1]. Energy production based on DER is supported by SG applications. In this context, priority is given to SG operations in order to find solutions that will provide distributed integration and effective management of DERs (solar, wind, biomass, etc.) in micro and macro scale grid which can show production discontinuity and uncertainty. At this point, there is a need for Micro Grid (MG) architecture in which the consumer subscriber model is widespread, and the local production and consumption strategy is dominated by the grid. These architectures have brought about problems of power systems such as distributed generation, distribution storage, as well as system management problems such as distributed control, distributed metering, optimal network management and energy balancing. The solution of these problems requires integration with the grid's communication and control systems to achieve a structure containing multi-layered technologies. In this multi-layer structure, to reach the effective transmission and distribution systems, correct communication technology must be applied to all the parameters on power system. If the competition evolves between communications infrastructure owners and requesting access to these structures with employees to serve in the same class of operators, a continuously increasing argument can be specified. As a result of this, it will be if consumers can access to energy in better quality and lower cost. Presently, the major point is communication system architecture design as an investigation for systems which can be used in interconnected MG applications in the future [2]. MG needs more sophisticated power flow ability as dual way communication at the same time. Therefore, it needs too much real time communication networks for energy sharing with data collection and processing [3]. The recent developments in technology and the growing concerns for global warming motivated engineers to research for more efficient systems. In order to decrease the impacts of fossil fuel-based generation on the environment, the new vision is to generate electricity from cleaner energy sources sited closer to the consumption areas. Consequently, the power industry is moving towards MG which may consist of renewables such as solar systems [4]. This also decreases the burden on transmission lines which already operates close to their limits. However, expectations of MG are not limited to energy sharing and transmission problems. Smart projections of near future envisage the sharing of data over the communication technology layer, not just the energy. This expectation promises a more complex and integrated, more interactive future where energy and knowledge are shared over the same infrastructure. Today's methods of sharing data will inspire the future energy sharing strategies. Traditionally, the strategy of static and one-way energy transmission from central producers to consumers will evolve into an architecture where smart grid applications and energy packages can be generated, stored and shared at any point in the grid. Transmission of energy packets in future MG such as transmission of data packets in digital data communication will be possible. It seems likely that all of the smart houses, smart cars and smart devices will become a molecular component of the MG. According to this development of energy, a MG design which uses distributed energy resources and can provide transmission and distribution by wired communication method as Power Line Communication (PLC), consisting of Photovoltaics (PV) and Electric Vehicles (EV) on grid architecture has been studied and its advantages have been discussed in this study. The paper is organised as follows. In Section 2, MG architecture designing has been investigated and the solutions to the problems for efficient energy transportation are discussed. The purpose of transmitting efficient energy is trying to improve the quality of energy by reducing losses and distortions. In order to solve the uncertainty of trying to control all of the smart energy network in this context, it is targeted to be divided into MG. The accuracy of the designed system that has been worked with real-time data is also tested for compliance with IEEE distribution and communication standards. In Section 3, PV integration as DER on-MG structure with communication technologies and EV applications simulations are studied. It is presented and discussed results obtained under the computational simulations with the major features of MG, including solving the energy quality problems, increasing the voltage quality, decreasing total harmonic distortion (THD) and even providing reactive power compensation by EV are investigated in Matlab. Conclusions are given in Section 4.

2. DESIGNED MICRO GRID SYSTEM

In this section, MG was designed that contains renewable resources and real customers to examine power quality and the effects of the use of DERs on DG.

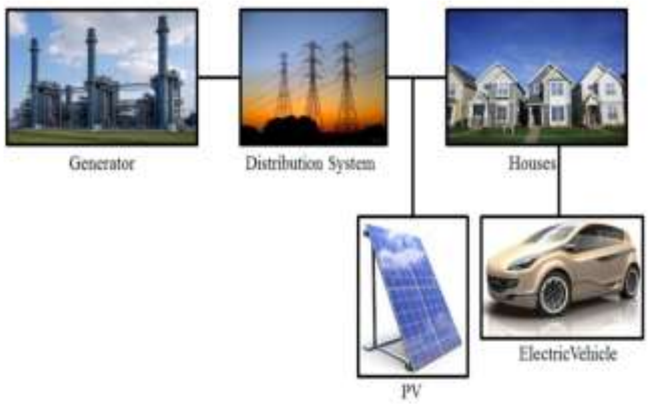

Fig -1: General structure of Micro Grid

The designed system infrastructure in block diagrams is shown in Fig. 1. And each part of it is examined following in detail. The generator block represents the utility grid and the system is designed to achieve best power transmission and distribution results with best power quality. Hence, the standards were applied each part of the system. To understand PVs connected points from different buses on MG affect the overall system. When designing a MG, what should be considered is how to respond to the real-time usage data of the design that runs without any problem in the simulation. For this purpose, the attention given to design the elements in the MG must be compatible with the IEEE and IEC specifications. Also, PV parameters effect on grid is clearly understood and all the data are collected from the Pecan Street [5], and then the MG design is started with this attentions as linear and non-linear elements must be applicable with IEEE 519 [6] and transmission line parameters must be applicable with IEC 61850 Standards [7]. Whether there is a significant reduction in the system and how it interacts with EVs; a new MG model has been designed. In the designed MG system, houses block provides 10 real houses are integrated to provide real time measured data communication which was obtained from Pecan Street [5]. It was important that the houses have the same specific characteristics such as Single-Family Home in the same region, Austin, Texas and total square foot and the number of electric devices they had, also the use of same model EV. Each house has an ID number from the Pecan Street database and approved to provide real time data. Mathematical modeling is an important step for running the data collected from the database in the Matlab. Therefore, the mathematical models of the designed houses are shown in Fig. 2. The data shown as Pgrid is the real–time consumption data from Pecan Street and this is transferred to the grid by separating it into the current and voltage values together with the parameters taken from the same database

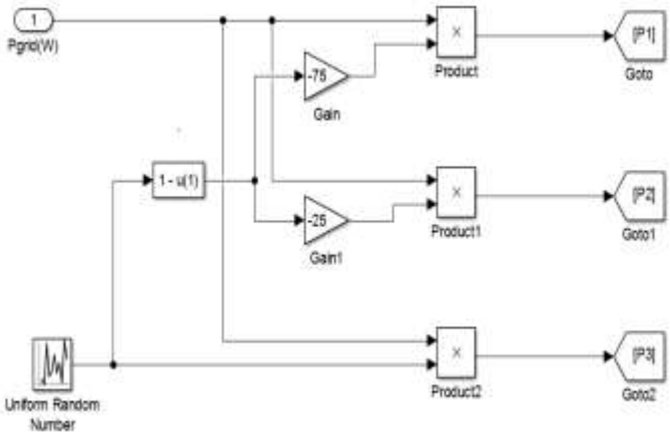

Fig -2: Mathematical modelling and distribution of house power in MG

Fig. 3 shows the calculation blocks in Matlab to measure current values for each house in MG. In general structure's distribution part, IEEE 13 bus distribution system has been modified to work with MGs which is shown in Fig. 4.

The IEEE standard requires about regulation of voltage that distributed generation resources should not take an active role [8]. Because of that, synchronous generators are used in MG system to control the power.

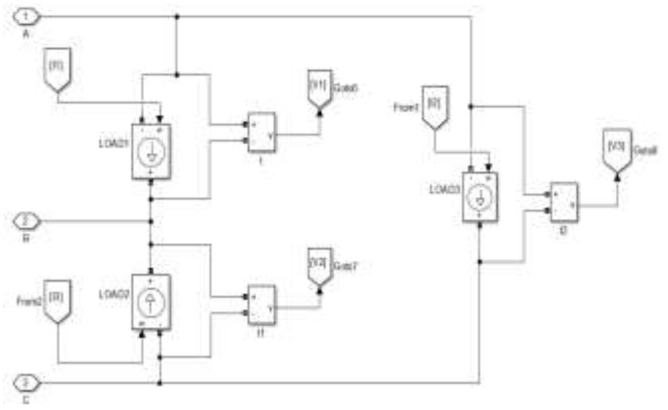

Fig -3: Calculation diagram of a phase current for each house

In this part of the study, real-time data will be run along with the parameters of standards. When the design of real time houses finished which is shown in Fig.2 and Fig.3, a problem occurred about the distribution of houses. To calculate impacts of electric vehicle and photovoltaics on grid, communication technology is required for a transmission line to distribute power. The previous studies of us [8] can be referred for a detailed explanation about smart communication technologies. Because of that, when solving the attenuation challenge of PLC technology, it can be possible to reach a more effective communication. In lights of our previous studies, in this study, harmonic impacts, and energy quality calculations are studied. The result of that, energy quality decreasing elements of communication are eliminated, and PLC technology is chosen for transmission and distribution of the system because it has many advantages on transmission and IEEE standards can be easily applied to the technology. Radial distribution data in this study are used to determine the best configuration that gives the maximum reduction of power loss [8, 9].

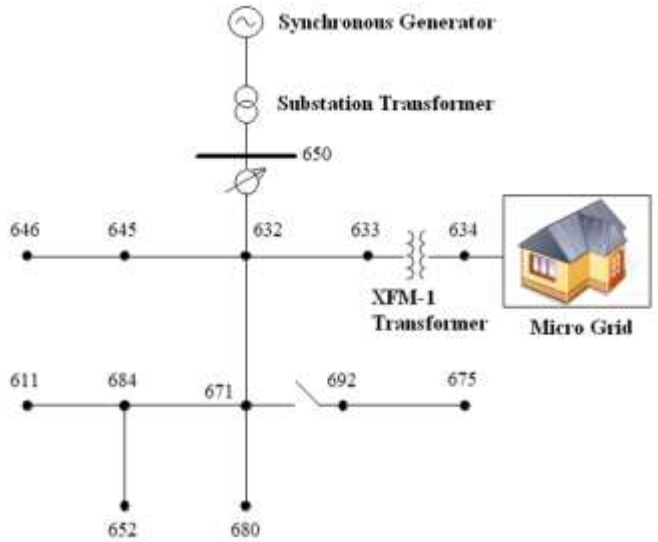

Fig -4: IEEE 13 buses modified system

Also during the designing process, all steps were taken to ensure that all other parameters met the standards. According to the general system structure of MG, Matlab model is designed and connected with IEEE 13 bus distribution system which shown in Fig.4, and then PVs are added with different situations to reach best quality of energy to understand the aim of this study. In the interconnection of DER based MG systems to such networks inevitably changes the characteristics of the system and presents key technical challenges which were previously unknown to grid operators and power engineers. Moreover, DER systems also make contributions to the fault currents around the network. Hence, in case of a fault, the characteristics of the grid become completely different and Figure 5 shows the matlab model of houses. The faults are only a few of the issues that have arisen in relation to the revolutionary changes occurring in the grids and the way they are operated. DERs have potential to reduce the overloads on the MG's transmission lines, strengthen the power quality, make the electric network more stable, and do not supply reactive power to the system. In cases where the synchronous generator is used, voltage and power coefficient control mode can be used for control. For this reason, simulations are run by holding 1 pu for voltage and 1 pu for power component.

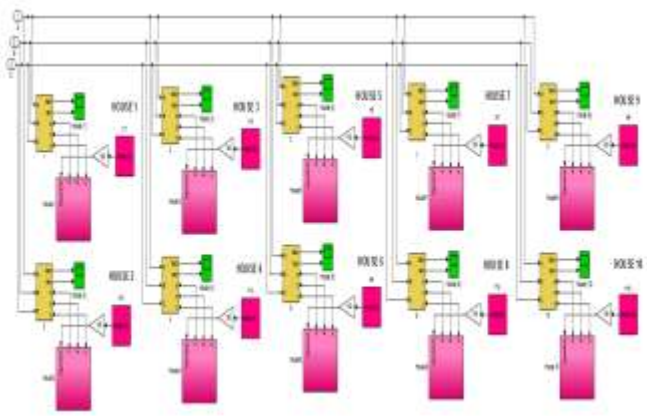

Fig -5: Matlab modelling of houses

To this end, the PLC infrastructure based on IEC 61850 has been implemented in Matlab Simulink Environment and the standards are applied to all the parameters of the designed system. And power quality indices are calculated. In the examination of power quality, the effect of harmonics is one of the most important points. The following equations have been used to reach the power quality results in the system. Computations were repeated for each bus by using the Simulated Annealing algorithm in Matlab [10]. The SA is used just compared with the standard values. The harmonic distortion (HD) in the distribution system occurred with the result of harmonic components, especially increased by the number of used power electronic elements.

The MG is designed in our system is defined as a harmonic load and connected to the network. DERs are integrated into the system in different states and harmonic effects, THD and crest factor changes are calculated. Therefore, the Total

Harmonic Distortion (THD) for voltage and current will be expressed as

$$THD_V = \frac{\sqrt{\sum_{n=2}^{\infty}(V_n)^2}}{V_1} \quad (1)$$

$$THD_I = \frac{\sqrt{\sum_{n=2}^{\infty}(I_n)^2}}{I_1} \quad (2)$$

THD Index in Load Bus has been calculated from

$$THDS = \frac{\sum_{n=1}^{K}(W_n.THD_n)}{\sum_{n=1}^{K}(W_n)} \quad (3)$$

where W_n is the weight factor at n^{th} bus, K is number of load bus and THD_n is index at n^{th} bus. DER effect on power quality is defined as a function of two main parts. After the indices of the buses in the system are calculated one by one, DER effect in these indices can be expressed as

$$THDS_V = \frac{THDS_{NO\_DER} - THDS_{DER}}{THDS_{DER}}.100 \quad (4)$$

Voltage change indices can be found from

$$VAD_V = \frac{VAD_{NO\_DER} - VAD_{DER}}{VAD_{DER}}.100 \quad (5)$$

where $THDS_{NO\_DER}$ is voltage amplitude of the bus before the DER, $THDS_{DER}$ is voltage amplitude of the bus after DERs are integrated. The system is designed in accordance with the smart grid infrastructure and supplied with distributed generation facilities and conventional distributed energy sources. It is aimed to develop our model in future studies to isolate the fault from the system after a possible break and try to change the communication methods of the data carrier transmission line. In this study, it is aimed to prevent the customers from being non-energized by using DER. Harmonics must be limited to specific standards when problems which occurred by the results of HD in the distribution grid can be eliminated. Table 1 shows the THD limits in IEEE 519 standards [6]. It is extremely necessary to limit the THDs to the standards in terms of reducing the additional losses which harmonics create in the system when using the elements in the system at full capacity [6], [7].

Table -1: Voltage distortion limits for harmonics

Bus Voltage	Individual V_b (%)	THDV(%)
V<69kV	3.0	5.0
69≤V≤161kV	1.5	2.5
V≥161kV	1.0	1.5

In order to operate the MG system and to be able to calculate the power quality, the EV total consumption data, which were obtained from the houses, have been examined. However, the point to be noted is that the real data needs to be examined for 24 hours because that the use of EVs differs over different times [11]. For use in power quality calculations and to avoid errors in real-time simulations, it was first reviewed monthly to find the highest load demand at the end of the transmission. Electrical daily demands researched for this work consist of real measured data from the huge Electrical Reliability Council of Texas (ERCOT) in database [12]. Measured data are collected for 10 houses from a cluster of single-family households located in north Texas during a year between May 2016 and May 2017. Then EV usage of these houses is compared for each month for 12 months with the purpose to find out which month the houses were used more. One-year data was analyzed, and the result is that the month of September 2016 has the biggest value of consumption as shown in Fig. 6.

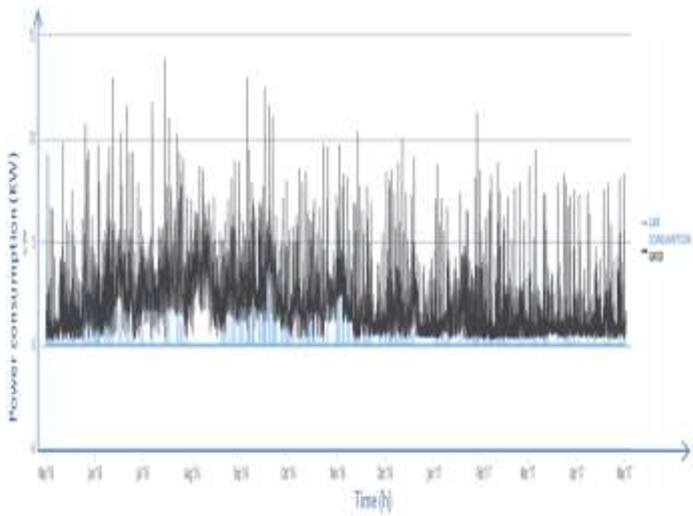

Fig -6: Total consumption graphs for 10 houses for a year. (Power Consumption(kW)-Time(h))

Several 10 days period was selected in the month of September, during which EV charge is heaviest. Fig. 7 shows the EV usage statistics of 10 houses in a period of a month on the illustrated chart. At least, in order to see the peak level of photovoltaic use in the same area, PV usage data for the same date range started to be collected from 10 houses selected randomly in the same area not using EVs. In order to do this, pecan street households using PV that do not use EV were found one by one, and the usage statistics of 153 houses in the same area in our study area was examined and tried to find the period where PV was used the most. It is expected to PV usage to be higher in summer, which sun is shining much more. The results of power consumption of PVs used in the system in September and confirmed by the US Annual Seasonal Climate Normal and Monthly Climate Normal reports on the Pecan street database [13], [14].

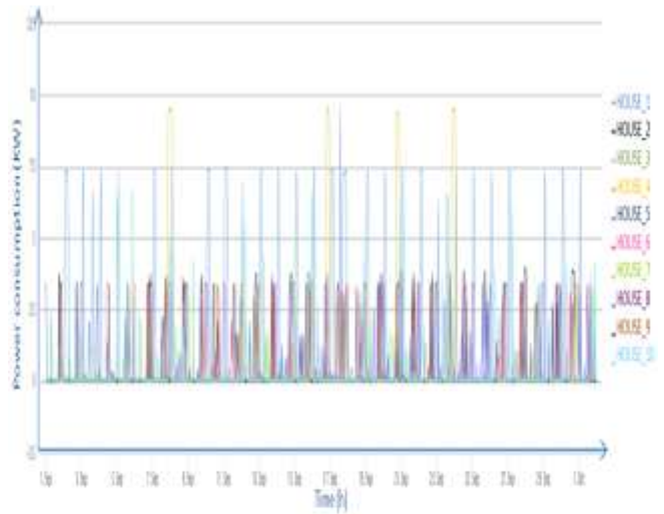

Fig -7: 10 houses total consumption graphs for month of September (Power Consumption(kW)-Time(h))

As the aim of the work is to visualize the times when the harmonic effects of the grid are biggest, it will be tried to analyze the transmission results with the highest PV power integrated into the system when the highest EV connected into the grid. The line parameters which were used in the system as the load and transmission line data are given in [15]. The active power of our MG system, which is connected with a number of 10 houses, was calculated as 10.552 MW and the results were also measured and approved in the simulation. Then, on an ideal micro grid, 25-30% of the system's total power needs to be met from distributed energy resources [16], PVs which have 2.5 MW power capacity connected to the grid and working with real-time EV data and the house data is entered into the system and an ideal MG system which has capable of real-time operation is created. This MG system is interconnected with the IEEE 13 bus system limited with the standards and power quality indices and crest factor values are calculated for each bus in Matlab. Then power quality calculations were analyzed for all cases to analyze the effects of PV integration and results in three different situations in the following section.

3. SIMULATIONS AND DISCUSSION

In this section, three different scenarios were considered, and the situation of the system was evaluated under these conditions. Test system, system data, harmonic load data are taken from relevant standards [6]. The harmonic load is connected to the B671 called B7 bus and the current values are determined by Matlab by load flow and harmonic analysis is done. THD and HD indices are calculated with voltage values for certain buses and for certain lines. The process of reducing these values and bringing them closer to the specified standards has been done by connecting the DER resources to the system in various parameters and shown by graphs and tables. The reason for using DER in different parameters is to find out how THD influences the voltage and current values of HD and to obtain the best site, power and being singular or distributed of the distributed production source.

The different situations mentioned are evaluated as follows.
Base
There is not DER connected with the houses.

Case 1
The system is supplied with one synchronous generator and 10 PV units each with a power of 250kW were connected to houses. The short distances between the houses were neglected. In this case, it is assumed that a PV power of 2.5 MW connected to the 634th bus. Simulations are run for 24 hours because the usage data of the consumers in the grid, that is the houses, are real-time.

Case 2
The system is supplied with one synchronous generator and separated to 5 pieces of PV plant each of has a 0.5 MW power and distributed from 634th, 645th, 675th, 680th, 684th buses. Simulations are run for 24 hours because the usage data of the consumers in the network, that is the houses, are real-time. Fig.8 shows an overview of the system.

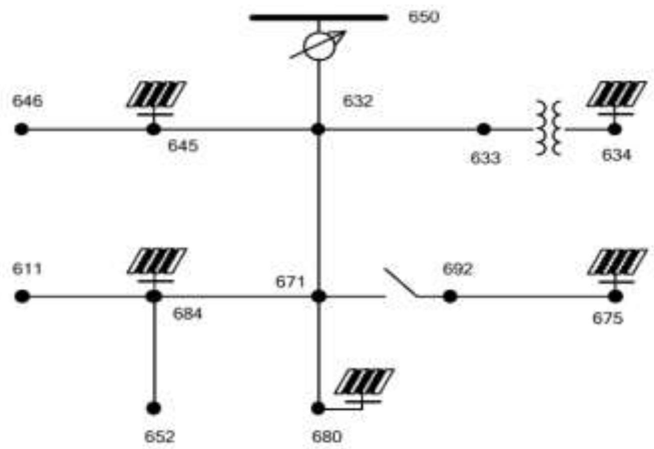

Fig -8: Illustration view of Case 2

Case 3
The system is supplied by one synchronous generator and one 3 MW of PV connected to a 675th bus which is farther from the entrance bus of the house.

The values of the effect of THD and quality indices on the work done for different situations are shown in Table 2 and 3. These values are calculated using Equation (1) and it also shows the percentages of the reduction of THD in the system after DER connections.

Table -2: THD (%) (Voltage) values for different situations

Bus	Base	Case1	Case2	Case3
B1	2,49	1,48	1,86	1,88
B2	2,45	1,46	1,83	1,85
B3	2,42	1,49	1,85	1,91
B4	7,79	4,51	6,49	7,31
B5	0,26	0,19	0,22	0,23
B6	2,42	1,49	1,85	1,9
B7	0,28	0,25	0,26	0,13
B8	2,42	1,43	1,74	1,92
B9	2,42	1,49	1,85	1,89
B10	2,45	1,45	1,65	1,88
B11	2,42	1,47	1,83	1,92
B12	2,47	1,46	1,88	1,9
B13	2,42	1,43	1,83	1,78

* Values shown in red are outside the IEEE limits.

The graphical illustration of THD(%) result is given in Fig. 8

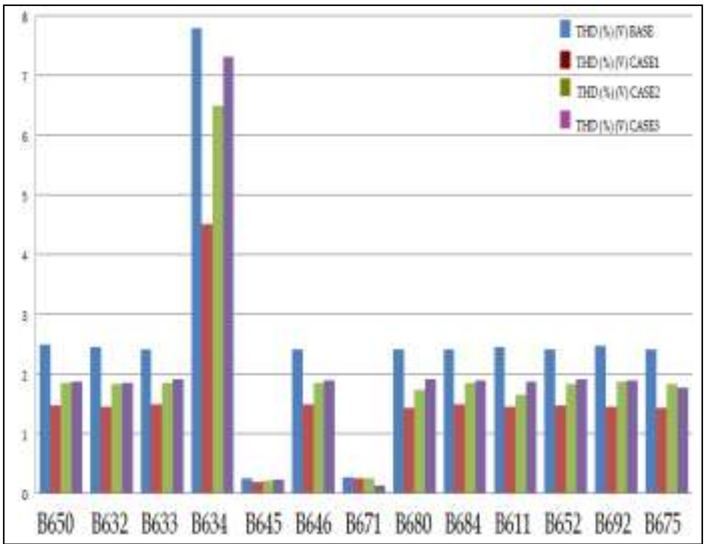

Fig -9: Voltage (THD) (%) of the 13-bus system for different situations

When the DERs are placed near the non-linear load in the system, the maximum decrease is achieved. But, when the same power is distributed by dividing and separating into 5 different buses, the harmonic voltage distortions also decrease. The decrease in THD after DERs are connected to the system can be displayed obviously in the Table 2, 3 and Fig.9. However, when the power of singular DER increased and connected close to the micro grid, harmonic reductions have been observed in the system, but in this case, the obtained values cannot reach the desired standard range. It can bee seen detailly in Table 2. On the test system, both close to the main grid and close to the harmonic source and the DERs sited number of B611, B634, B646, B650, B671, B680 buses and the most significant odd voltage harmonics which are H5 (Fifth Harmonic), H7 (Seventh Harmonic), H11 (Eleventh Harmonic) shown in Table 4 with comparisons on the different cases.

Table -3: THD (%) (Voltage) change percentages relative to the base values for different situations

Bus	Case 1	Case 2	Case 3
B1	44,25331232	21,78564263	14,45685526
B2	44,96247844	22,22154558	14,54758651
B3	44,78859658	22,12564856	14,54215487
B4	49,35463378	17,58469764	8,356245865
B5	47,75548565	21,84576582	13,78547856
B6	44,78859658	22,12564856	14,54215487
B7	39,52535172	27,2546858	13,55478546
B8	44,98113208	28,88679245	14,45658456
B9	44,78859658	22,12564856	14,54215487
B10	41,86046512	27,44186047	14,13721409
B11	44,88845265	22,22053558	14,56546214
B12	44,77859658	32,94562145	14,65482563
B13	44,65248568	27,12547843	14,57924528

The values given for the three cases in the Table 4 are shown graphically in Fig. 10.

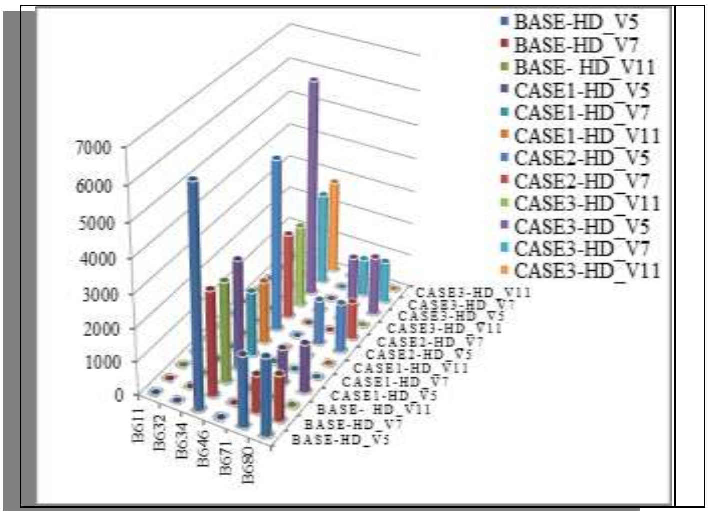

Fig -10: Voltage (THD) (%) of the 13 bus system for different situations

Table 4 suggests, when DERs are placed near the non-linear load in the system and singularly, the maximum decrease in HD._V values and the harmonic voltage distortions decrease again when the same power distribute with 5 buses. But, when the power increases a little and connects a single load to the bus close to the grid, harmonic reductions are observed in the system. But in this case, HD._V values cannot stay in the standard range. In addition, when the DERs are connected to the bus where the nonlinear load is connected, it is determined that the current harmonics are decreased and shown numerically in Table 5.

Table -4: Voltage harmonic distortions of buses placed closer the grid and DERs

	Base		
	HD_V5	HD_V7	HD_V11
B611	0.087	0.041	0.004
B632	0.081	0.035	0.004
B634	6.486	3.135	3.004
B646	0.078	0.032	0.003
B671	2.121	1.122	0.215
B680	2.307	1.373	0.545
	Case 1		
	HD_V5	HD_V7	HD_V11
B611	0.062	0.043	0.013
B632	0.051	0.032	0.003
B634	3.254	1.932	1.855
B646	0.048	0.029	0.002
B671	1.071	0.699	0.196
B680	1.454	0.898	0.278
	Case 2		
	HD_V5	HD_V7	HD_V11
B611	0.08	0.042	0.005
B632	0.07	0.03	0.004
B634	5.12	2.564	2.456
B646	0.06	0.02	0.003
B671	1.35	0.915	0.121
B680	1.46	1.117	0.311
	Case 3		
	HD_V5	HD_V7	HD_V11
B611	0.084	0.052	0.004
B632	0.074	0.041	0.003
B634	6.457	2.745	2.814
B646	0.063	0.032	0.002
B671	1.541	1.125	0.158
B680	1.758	1.252	0.324

However, the current harmonics are examined near the lines and the generators, it is seen that the most significant odd current harmonics in the lines are higher than the grid side as the line current is higher on the generator side.

Table -5: Current harmonic distortions of grid and generator side for different situations

Line 650-632	Base	Case 1	Case 2	Case 3
Line Current(A)	78,75	78,58	78,36	78,25
HD._I5 (%)	10,785	9,865	11,655	13,254
HD._I7 (%)	4,546	4,578	6,154	7,547
HD._I11 (%)	0,54	0,56	0,654	0,755
THD. _I (%)	10,886	10,116	13,456	15,454
Line 633-634				
Line Current(A)	54,76	35,45	35,31	31,54
HD._I5 (%)	2,99	2,121	2,147	2,245
HD._I7 (%)	0,335	0,215	0,341	0,354
HD._I11 (%)	0,154	0,098	0,124	0,145
THD. _I (%)	3,11	2,456	2,874	2,871

Table -6: Voltage profile indices results for different situations

Bus	Base	Case1	Case2	Case3
B650	1	1	1	1
B632	0,9972	0,9991	0,9994	0,999
B633	0,9986	0,9997	0,9993	0,9996
B634	1,0031	1,0172	1,0181	1,0178
B645	0,999	1,0021	1,0058	1,0024
B646	0,9954	0,9965	0,9978	0,9968
B671	0,9957	0,9969	0,9974	0,9971
B680	0,9951	0,9963	0,9972	0,9965
B684	0,9855	0,9874	0,9912	0,9899
B611	0,9951	0,9968	0,9979	0,9971
B652	0,9817	0,9872	0,9891	0,9878
B692	0,9971	0,9985	1,0023	0,999
B675	1,0052	1,0078	1,0092	1,0081

Finally, the system's voltage profile is also examined for all the scenarios. Load flow analyzes were performed in the system to compare the conditions before and after DER is connected and voltage profiles and voltage change indices are presented in Table 6 and 7. The removal of a voltage profile is a commonly used method of energy quality. The study of improving the voltage profile and voltage regulation of the transmission lines is useful to reach energy quality analysis of the system. It can be examined in Table 6 and Table 7, the usage of DERs moved voltage values of the system upward. As the connection point and power capacity of DERs changed; the voltage profile has also changed by linearly.

Table -7: Voltage change profile indices (%) values for different situations

Bus	Case1	Case2	Case3
B650	0	0	0
B632	-0,19	-0,22	-0,27
B633	-0,07	-0,21	-0,1
B634	-0,4	-0,5	-0,47
B645	-0,31	-0,59	-0,25
B646	-0,09	-0,24	-0,14
B671	-0,12	-0,22	-0,24
B680	-0,12	-0,21	-0,24
B684	-0,22	-0,67	-0,44
B611	-0,17	-0,27	-0,2
B652	-0,55	-0,74	-0,61
B692	-0,14	-0,32	-0,88
B675	-0,26	-0,4	-0,29

The graphical contrast of the voltage profile is shown in Fig. 11. Voltage change indices are calculated according to Equation (5).

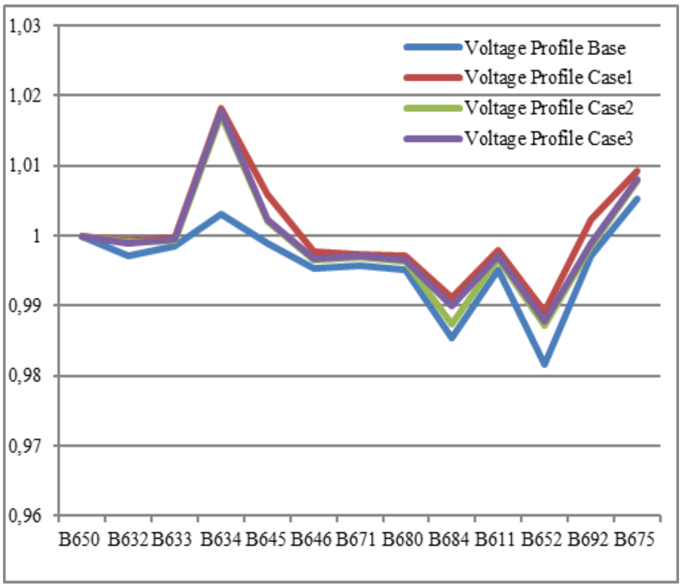

Fig -11: Voltage (THD) (%) of the 13-bus system for different situations

The analysis of all the results will be evaluated in detail in the next section.

4. CONCLUSION

In this study, the impacts of a 2,5 MW solar power generator with EVs communicate with PLC on the grid were investigated. For this system, it has been pointed out that PLC provides real time power to DERs and EVs. A renewable micro grid system was designed and the voltage profiles at the output were examined. DERs was incorporated to study the voltage profiles in the system according to different cases. When it is aimed to increase the quality of the energy distributed from the grid, there is no exact standard for how DERs will be connected to the grid. The IEEE 519 and IEC 61850 Standards are used for achieving the best quality of energy transmission. Also, communication and control effects examined in this study. On this basis, this work pointed out that power instability in large transmission systems can be minimized, and the fluctuations caused by the location of renewable energy sources to the system can be diminished. The results are consistent with similar studies [17-31]. Some studies use communication point, some studies interest about control, and one of the most important features of our study, separating it from other studies, is that it is applied with real consumption values from real houses, as well as complying with the standards. And this study uses new PLC method for communication which is modeled for best attenuation values in our previous studies [8, 18]. Connection points of DERs which are close to the grid side or the load side effects the quality of the energy transmitted in the grids at different levels. These proposed solutions are contemporary and popular topics that have been studied nowadays. The outputs obtained in accordance with the thesis work are presented below;

- In the literature review, also incompleteness of an important need is observed. That is the establishment of an official site to communicate with suppliers, sellers, producers, and scientists of environment-friendly vehicles in our country. In this way, employees can be informed about others working on the subject in question.
- Examining the work done and the literature review, one of the major obstacles to the widespread adoption of PVs is that standard structures have not yet been established in some countries. Every firm, academy, R&D laboratory is working independently from the others and as a result, everyone is heading in different directions. If certain standards are already established in our country for PV and EV systems, then much faster advance will be experienced.
- In this study, efforts have been made to solve possible problems in connection with renewable energy sources and energy quality issues. By means of the proposed system, it will be possible to connect extra EVs by reducing the harmonic distortions on the grid depending on the characteristics of the connection point. The designed system can give even more successful results than conventional systems even in today's grid structure.
- This study is expected to help EV owners meet the energy needs of certain critical loads from PVs and

at the same time contribute to the use of vehicles with DERs.

- Studies have shown that when the recommended grid connection system is finalized, it will be able to provide many probability solutions in connection of PVs to the grid. Thanks to this system, problems caused by harmonic distortions can be reduced. In this way, the PV power that can be connected to the grid from a connection point can be increased or the charging time of the vehicles can be reduced. During this process, the quality of the energy delivered to the consumer wills do not deteriorate.
- The performance of the system under different PV powers has been checked during the conducted studies. The PVs were integrated into the system from different points and different capacities, and the change in grid current and voltage was investigated. In this case, this system will benefit the system by producing solutions to the energy quality problems of distribution grid.
- The proposed SA algorithm for testing under different cases has tried to keep the harmonics of grid between the IEEE standard limits. However, in some cases, the grid produced non-standard results. These results show that it is not advised for each house to use its own PV technology but using central PV power to increase the quality of the energy delivered to the consumer should be encouraged.
- If the usage of PV and EV are widespread, the extra load on the grid will require making new investments. When these investments are made, the efficient use of existing transformers instead of replacing them with new transformers will result in lower costs and the efficiency of the systems will be increased considerably. For this purpose, PLC method is used as an existing communication system. The PLC allows solving the electrical energy quality problems such as power interruption, voltage fluctuations, voltage drop and rising with its behavior used with the smart grid communication infrastructure.
- Without micro grid infrastructure, it is not possible for these systems to evolve at the desired level, so EV systems must be considered together with smart grids.
- The study on Smart Houses which have a connection between PV and EV, have shown that energy savings can be achieved if EVs are considered together with PVs to achieve significant savings.

A future work perspective is to experimentally develop this system which is tested in a simulation environment and perform tests and further R&D activities in laboratory environment with funding scientific and technological research council of turkey (TUBITAK).

The major objective of this study was to investigate the effects of the DERs on the voltage harmonics, power quality indices of MG system with the EV for changing parameters such as power, system position, singularity or spreading. Also, the harmonics reduction on LV networks is aimed. The study was conducted on an IEEE 13 bus distribution system. As it can be concluded from analyzes;

- A general improvement in the tension profile was observed in the presence of DER.
- If DERs are connected to non-linear load bars, then the harmonics reduction rate will be higher.
- The presence of DER reduces the harmonics in the bus voltages and increases the voltage harmonics of the lines close to the MG. In this case, it is more advantageous to use a single system of DERs in the system. The increase in the power of the DERs will further reduce the bus voltage harmonics.

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