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Original Article

Experimental Study on Power Quality Analysis of Hybrid Energy System

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Abstract *- In the recent era, the economy of every country depends upon its consumption of electricity, which is increasing over time. to meet the growing demand for electricity and save the environment, we started to shift our power generation towards renewable resources. the main problem with this is that we cannot rely on it as it is sometimes not available due to weather conditions. So the finest solution for this is to use a hybrid energy system for the best utilization of all resources. in this paper, the power quality analysis is done experimentally to determine which power quality issue has a major impact on power systems at different generation systems. This paper defines the hybrid energy system as an emerging technology, but the power quality issues related to this* are *difficult to handle. So a comparative study has been done to analyze the power quality problems in a different generation type.*

Keywords *- Power quality issues.*

I. INTRODUCTION

Electrical energy plays an important role in today's lifestyle. Intending to lead a higher quality of life in this era, the demand will increase in all sectors [1]. With increasing technological progress, electricity has become a basic need in our lives. We have become so reliant on electrical power that even the idea of living in a world without electricity is terrible. Research revealed that 50% of the public polled that without electricity, they would not be able to survive for more than 2 weeks, proving our level of dependency on electric power. of those surveyed, 75% astoundingly predicted that they would be dead within two months [2].

Now, renewable energy resources are a wonderful alternative to power generation with no pollution or affecting nature and the atmosphere. the main snag of solar or wind is that the flow of wind and sunlight's intensity is highly volatile and unpredictable, and it varies with disturbances in nature. Therefore it is difficult to get a continuous and reliable supply. to resolve this issue, different renewable sources are used together to form a hybrid system later coupled with the main grid to overcome the power shortage in a certain area.

Unfortunately, the coupling of the main grid system with renewable sources makes the power system complicated complex which creates power quality problems [3]. These problems are very threatening for an entire power system.

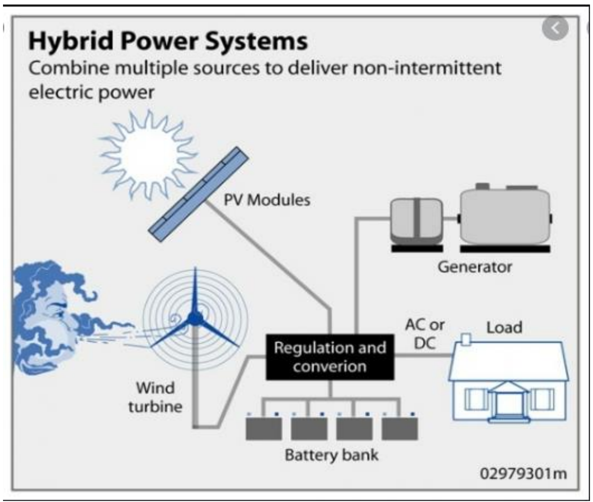

Fig. 1 Interconnection of Conventional with renewable [3]

When the system is a hybrid energy system, the power quality issues vary with the load, which must be compensated to maintain stability and synchronism. Integration of these non-conventional sources-based distributed generations systems to the utility grid (Hybrid Energy system) usually faces power quality issues related to the grid and various loads.

II. LITERATURE REVIEW

In the previous literature, Solar PV Wind Hybrid Energy System has been used, part of the energy demand for farmhouses, small companies, private homes, educational organizations, small companies, educational organizations or apartment houses depending on the demand at the point of use, electricity is obtained from wind and solar power. It reduces dependency on a single source and improves reliability. Thus, we can restore system performance compared to a separate build mode of generation [4].

The PV-Wind hybrid power system is the soonest option to generate electricity instead of fossil fuel producers. This work will provide a MATLAB model of a PV wind hybrid power system. the model will provide key information for each part of the PV wind hybrid system.

This model will include photovoltaic power subsystems, wind power subsystems, inverters, and battery spare parts. Photoelectric energy is converted to AC using inverters and wind energy using turbines, and the energy produced is stored in the battery and discharged when needed. This hybrid is valuable for both industrial and domestic use. This reduces the requirement for a single source because it has multiple sources [5].

Soro Sielle Martin's new renewable energy laboratory concept was based on solar, wind, and biodiesel energy sources. Hybrid power systems, the physical environment of the laboratory, the virtual phase of the laboratory, and the impression of e-learning were represented. Wind power systems, solar power systems, and biodiesel generator working principles and dimensions and simulations were shown. the simulation results determine that solar panels and wind turbines are non-linear systems, and MPPT control must be implemented to work at extreme power points to increase efficiency. Moreover, the solar system and the evolution of WECS currents show that batteries are significant energy in renewable energy systems because they can store energy during the construction period of high renewable sources and provide energy to load during short production periods [6].

The distributed off-grid hybrid system of wind, FC, and solar was developed and proposed for the reliability of electrical energy by using the backup battery. the proposed system has important elements influencing energy control, which are capturing power from renewable resources. PLC is also used to improve the efficiency of electricity generation. an article is about the organization of two solar and wind renewable energy systems, known as hybrid renewable energy (HRES). This distributed hybrid energy system is suitable for accessing energy in rural areas where it is impossible to connect to the grid during the year. in this work, the radiation level of the solar PV module for variable conditions using the Additional Conductance (IC) Method MPPT algorithm and PMSG Generator wind speed governor are planned and analyzed using PI controller independently and connected to store energy as a hybrid system. Additional energy and both systems are connected via an inverter with RL load, i.e., the autonomous system is designed and analyzed using MATLAB / SIMULINK. [7]

The research says that a hybrid solar-wind system is the best generation system. Where management cannot reach, and transmission is difficult. to reduce the cost of transmission, we can install the hybrid system directly. This study will be useful for implementing a hybrid system in the future. the chart is useful to understand the annual generation of energy generated throughout the year in India by different power generation systems. A paper contains a solar photovoltaic system and a wind power generation system; in this hybrid system, the wind turbine can be used to produce electricity when the wind can be obtained, and the solar panels are used when solar radiation can be obtained; both sections can generate power at the same time. the battery procedure is to provide an uninterruptible power supply. This system consists of a 20 W solar panel, 3 W wind turbine / 48 v generating system voltage, the battery is 12 V, and inverter rating (VA) 25 sine wave output and 230 V AC output / 50Hz AC frequency [8].

III. METHODOLOGY

To analyze the power quality issues, we need to design a system that synchronizes conventional power with renewable one. for this purpose, a model has been designed that first takes input from different sources, combines it into one, and then gives output. This model is designed while keeping in view the mandatory frequency and voltage constraints for the synchronizing purpose.

The designed model takes 2 renewable inputs wind and solar energy. the solar input voltage is 12 volts, while the 3 phase input voltage of wind is 120 volts.

This model takes the DC solar source and sends it to the DC bus bar through MPPT. From the second input, it takes a three-phase AC supply of wind turbine and then rectifies it, and then sends it to the dc bus bar. Batteries are also connected to the bus bar, so they may store energy during peak and supply it later. the output of the bus basis is connected to an inverter and then supplied to the load.

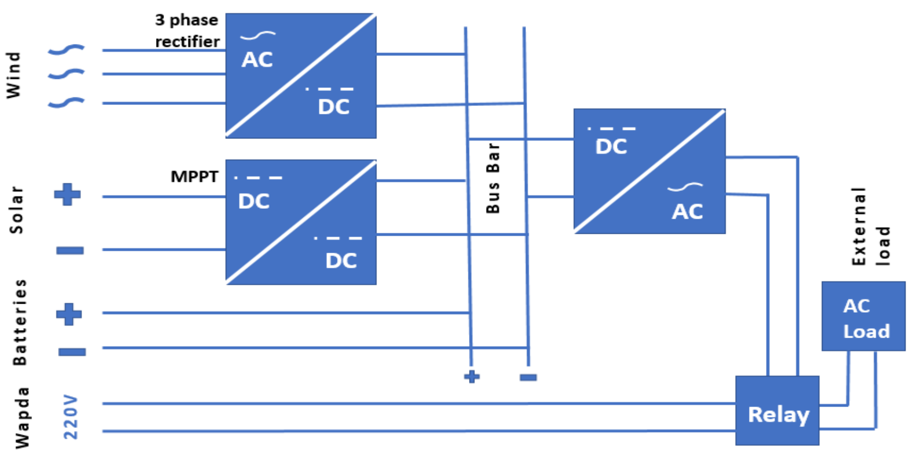

Fig. 2 Schematic diagram of the hybrid system

IV. RESULTS AND DISCUSSION

To analyze the power quality issues of the renewable and hybrid systems, we first take different renewable sources like wind and solar and analyze which power quality issues may arise when we have these sources of power.

A. Power Quality Issues in Wind Generation

Below are the results of power quality issues when we have wind generation.

In figure 3 of appendix A, the different loads are switched on wind generation, and the voltage levels are observed. in resistive load, the voltage levels are at normal values of 210V. in inductive load, the voltage level gets down up to 195V, while in capacitive load, the voltage level increases up to 225V. the further waveform is switching of random load and hence has a fluctuating pattern.

Figure 4 of appendix A shows that the different loads are switched on wind generation, and the current levels are observed. in resistive load, the current has values of 0.12amps to 1.25amps. in inductive load, the current is from 0.30amps to 1.0amps, while in capacitive load, the current level gets 0.25amps to 0.95amps. the random switching.

Figure 5 of appendix A shows the frequency unbalance while switching resistive load in the wind. as the system starts and the resistive load is switched on, the system's frequency will increase from 50 to 50.26 and then decrease and stable up to 50.23.

Figure 6 of appendix A shows the frequency unbalance while switching capacitive load in the wind. as the system starts and the capacitive load is switched on, the frequency of the system goes down from 50.234 to 50.231 and then increases up to 50.239

Figure 7 of appendix A shows the frequency unbalance while switching inductive load in the wind. the system frequency varies with the switching of load from 50.2337 to 50.231 and then decreases up to 50.2315 with maximum inductive load.

Figure 8 of appendix A shows the V & I harmonics while switching resistive, inductive, and capacitive load in the wind. the % of V harmonic is 7.5% at the time of resistive load, 21% at inductive load, and 17% when the load is capacitive. the current harmonics are 10% at resistive, 310% at inductive, and 120% at the time of capacitive load.

B. Power Quality Issues in Solar Generation

Following are the results of power quality issues when solar power generation.

In figure 9 of appendix B, the different loads are switched on solar generation, and the voltage levels are observed up to 220V normally. Still, the voltage levels become unexpectedly high when the capacitive load is switched on.

In figure 10 of appendix B, the different loads are switched on solar generation, and the current levels are observed from 16 amperes to 32 amps according to the load. Here, the results clearly show the waveform distortion on the inductive and capacitive load increase.

Figure 11 of appendix B shows the frequency unbalance while switching resistive, inductive, and capacitive load in solar. in the above wave, the system's frequency starts from 50.25 and goes to 50.12. the system's frequency suddenly drops when the capacitive load is switched, and then with further inductive load, the frequency maintains to 49.83 and then goes to 50.05 when the load is switched off.

Figure 12 of appendix B shows the V & I harmonics while switching resistive, inductive, and capacitive load in solar. the % of V harmonic is 32% at the time of resistive load, 39% at inductive load, and 34% when the load is capacitive. the current harmonics are 40% at resistive, 72% at inductive, and 80% at the time of capacitive load.

Figure 13 of appendix B shows the V & I waveforms while switching resistive load in solar. in that wave, the voltage wave is a sine wave with a peak value of 320V. the current wave has a value from 0 to 0.85 amps.

Figure 14 of appendix B shows the V & I waveforms while switching inductive load in solar. in that wave, the switching of the inductive load is done on solar and analyzed that the voltage wave is not even a pure sine wave and has a maximum value of almost 300V. the current waveform has a maximum value of -1.55amp.

Figure 15 of appendix B shows the V & I waveforms while switching capacitive load in solar. in that wave, the switching of the capacitive load is done on solar, and analyzed the quality issue of a pure sine wave with a maximum value of almost 310V. the current waveform has a maximum value of 0.85amp.

Figure 16 of appendix B shows the V & I waveforms while switching resistive, inductive, and capacitive load in solar. in that wave, the switching of the combination of the load is done on solar and analyzed. the voltage wave does not vary much from the previous waveforms and has a maximum value of 300V, but the current waveform has more distortion. the current waveform has a maximum value of -12 amps to 13amps.

C. Power Quality Issues in Hybrid Generation

Using the prototype described above, a hybrid system is made, and the power quality issues are analyzed.

Figure 17 of appendix C shows that the different loads are switched on hybrid generation, and the voltage levels are observed. the switching of the combination of loads is done on a designed hybrid system and analyzed that the voltage levels are from 15V to 123.28V. the sudden voltage drop occurs when the capacitive load is switched on with a major quantity.

Figure 18 of appendix C shows that the different loads are switched on hybrid generation and the current levels observed. the current waves are analyzed on a designed hybrid system and observed that current levels are from 0 am to 29.3 amps. the maximum loading faced by the hybrid system at the time of capacitive load.

Figure 19 of appendix C shows the frequency unbalance while switching resistive, inductive, and capacitive load in the hybrid system. the maximum frequency of the system is 50.284. the system's frequency shows abnormal behavior when the capacitive load is switched on.

Figure 20 of appendix C shows the V harmonics while switching resistive, inductive, and RL load combinations in hybrid. the % of V harmonic is 45% at resistive load and inductive loading. the voltage harmonics reach 130% when the RL load is switched.

Figure 21 of appendix C shows the I harmonics while switching resistive, inductive, and RL load combinations in hybrid. the current harmonics are 50% at resistive, 70% at inductive, and 90% at the time of RL load.

Figure 22 of appendix C shows the V & I harmonics while switching capacitive load in hybrid. the % of V harmonic is 54%, and the current harmonics are 74% at capacitive load switching.

Figure 23 of appendix C shows the V & I waveforms while switching resistive load in hybrid. in that wave, the switching of the resistive load is done on a hybrid system, and analyzed the quality issue of the pure sine wave has a maximum value of almost 200V. the current waveform has a maximum value of 1.55amps.

Figure 24 of appendix C shows the V & I waveforms while switching inductive load in hybrid. in the figure, the V&I waves of inductive load are analyzed, having a voltage value of 200V and a current maximum value of 2 amps. Here you can observe the change of current wave at heavy inductive load.

Figure 25 of appendix C shows the V & I waveforms while switching capacitive load in hybrid. in that figure, the V&I waves of capacitive load are analyzed, with a voltage value of 190V and current values from -20 amps to 36 amps. Here you can observe the difference between the current wave and from previous one.

V. CONCLUSION

By analyzing the previous results, it is concluded that the system is more prone to power quality issues when the major load is capacitive.

The power quality issues will be more in the hybrid system than in pure renewable or conventional system.

Power quality issues will increase up to 2.5 times if the system changes from conventional to renewable.

The harmonics can increase up to 8 times if the system shifts from conventional to hybrid.

As the power quality increases in the hybrid system, the system needs more protection and filters to increase the system's reliability.

REFERENCES

[1] Menon, Vivek, and M. Hashem Nehrir. A Hybrid Islanding Detection Technique Using Voltage Unbalance and Frequency Set Point. IEEE Transactions on Power Systems , 22(1) (2007) 442-448.

[2] Qadir, Sikandar Abdul, Hessah Al-Motairi, Furqan Tahir, and Luluwah Al-Fagih. Incentives and Strategies for Financing the Renewable Energy Transition A Review. Energy Reports 7 (2021) 3590-3606.

[3] Swain, Goutam, Pampa Sinha, and M. K. Maharana. Detection of Islanding and Power Quality Disturbance in Micro Grid Connected Distributed Generation. in 2017 International Conference on Innovative Mechanisms for Industry Applications (ICIMIA), (2017) 388-393 IEEE.

[4] Godson, J., M. Karthick, T. Muthukrishnan, and M. S. Sivagamasundari. Solar PV-Wind Hybrid Power Generation System. International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, 2(11) (2013) 5350-5354.

[5] Srikanth, M., T. Vijay Muni, M. Vishnu Vardhan, and D. Somesh. Design and Simulation of PV-Wind Hybrid Energy System. Jour of Adv Research in Dynamical & Control Systems, 10 (2018) 999-1005.

[6] Figueiredo, João, and Joao Martins. Energy Production System Management–Renewable Energy Power Supply Integration With Building Automation System. Energy Conversion and Management, 51(6) (2010) 1120-1126

[7] Laghari, Intakhab Alam, M. Ali Tunio, Rameez Shaikh, and Noman Khan. Development and Performance Analysis of Small Scale Proto Type Model for Hybrid Power Generation SSRG International Journal of Electrical and Electronics Engineering (SSRG - IJEEE), 7(2) 2020.

[8] Al-Kandari, Ahmad, Mahmoud Gilany, and A. Shaltout. A PLC Controller Algorithm for Optimum Operation of Photovoltaic-Battery System. in 2006 Large Engineering Systems Conference on Power Engineering, (2006) 112-118. IEEE.

[9] Gupta, Tripurari Nath, Shadab Murshid, and Bhim Singh. Power Quality Improvement of Single Phase Grid Connected Hybrid Solar PV and Wind System. in 2018 IEEE 8th Power India International Conference (PIICON), (2018) 1-6. IEEE.

[10] Acharya, Sampad, Rudranil Ghosh, and T. Halder. an Adverse Effect of the Harmonics for the Power Quality Issues. in 2016 International Conference on Computational Techniques in Information and Communication Technologies (ICCTICT), (2016) 569-574. IEEE.

[11] Meitei, Ngerangbam Manichal, Divakar Tamang, and Sarsing Gao. A New Harmonic Analysis Reporting Technique to Improve Power Quality in Distribution System Network Applications. in 2021 International Conference on Advances in Electrical, Computing, Communication and Sustainable Technologies (ICAECT), (2021) 1-5. IEEE.

[12] Khan, Muhammad Umar, Et Al. S oft Computing Approach for Classification of Complex Power Quality Events. International Conference on Artificial Intelligence (ICAI). IEEE, (2021).

[13] Beig, Hikmat, Savita Nema, and Suresh K. Gawre. Power Quality Issues and Mitigation Approaches for Modern Power Scenarios Encapsulation. in 2020 IEEE International Students' Conference on Electrical, Electronics and Computer Science (SCEECS), (2020) 1-6. IEEE.

[14] Mageed, Hala, Adel S. Nada, Salama Abu-Zaid, and Rehab S. Salah Eldeen. Effects of Waveforms Distortion for Household Appliances on Power Quality. MAPAN, 34(4) (2019) 559-572.

[15] Nejabatkhah, Farzam, Yun Wei Li, and Hao Tian. Power Quality Control of Smart Hybrid AC/DC Microgrids an Overview. IEEE Access, 7 (2019).

[16] Ghosh, Sagnika, Mohd Hasan Ali, and Dipankar Dasgupta. Effects of Cyber-Attacks on the Energy Storage in a Hybrid Power System. in 2018 IEEE Power & Energy Society General Meeting (PESGM), (2018) 1-5. IEEE.

[17] Tamboli, Arif S., and H. T. Jadhav. Hybrid STATCOM for Reactive Power Compensation. 2018 International Conference on Current Trends Towards Converging Technologies (ICCTCT). IEEE, (2018).

[18] Jayasankar, V. N., M. V. Gururaj, and U. Vinatha. A Study on Hybrid Renewable Energy Source Interface to the Non-Ideal Grid At Distribution Level With Power Quality Improvements. in 2016 IEEE 6th International Conference on Power Systems (ICPS), (2019) 1-5. IEEE.

[19] Sarma, S. Subramanya, D. Gangadhara Reddy, Ch SKB Pradeep Kumar, and P. Devdass. Large Scale Synchronization of Hybrid Distributed Generation Sources to the Low Voltage Grids. in 2017 International Conference on Energy, Communication, Data Analytics and S oft Computing (ICECDS), (2017) 443-448. IEEE.

[20] Galván, Luis, Juan M. Navarro, Eduardo Galván, Juan M. Carrasco, and Andrés Alcántara. Optimal Scheduling of Energy Storage Using A New Priority-Based Smart Grid Control Method. Energies, 12(4) (2019) 579.

[21] Koca, Yavuz Bahadır, Yüksel Oğuz, and Ahmet Yönetken. Investigation Efficiency and Microcontroller-Based Energy Flow Control for Wind-Solar-Fuel Cell Hybrid Energy Generation System With Battery Storage. Measurement and Control , 50(7-8) (2017) 159-168.

[22] Longo, Michela, Wahiba Yaïci, and Federica Foiadelli. Hybrid Renewable Energy System With Storage for Electrification–Case Study of Remote Northern Community in Canada. Int. J. Smart Grid , 3(2) (2019).

[23] Lobo, Eodia Tasik Sedan, and Matius Sau Rombe. PROTOTYPE OF A SMALL (SOLAR-WIND) HYBRID POWER PLANT. International Journal of Mechanical Engineering and Technology (IJMET), 10(5) (2019) 274-282.

[24] Somwanshi, Devendra, and Anmol Chaturvedi. Design and Optimization of A Grid-Connected Hybrid Solar Photovoltaic-Wind Generation System for an Institutional Block. in International Conference on Artificial Intelligence Advances and Applications, (2019) 319-326. Springer, Singapore.

[25] Suresh, M., and R. Meenakumari. Optimal Planning of Solar PV/WTG/DG/Battery Connected Integrated Renewable Energy Systems for Residential Applications Using Hybrid Optimization. International Journal of Industrial Engineering 2(1) (2018) 15-20.

[26] Kumar, Hemanth, G. Tejaswini, and Anupama Hongal. Hybrid Power Generation Using Non-Conventional Energy Sources. Perspectives in Communication, Embedded-Systems and Signal-Processing-Pices, 2(12) (2019) 316-318.

APPENDIX A

Results of Power Quality Issues in Wind Generation

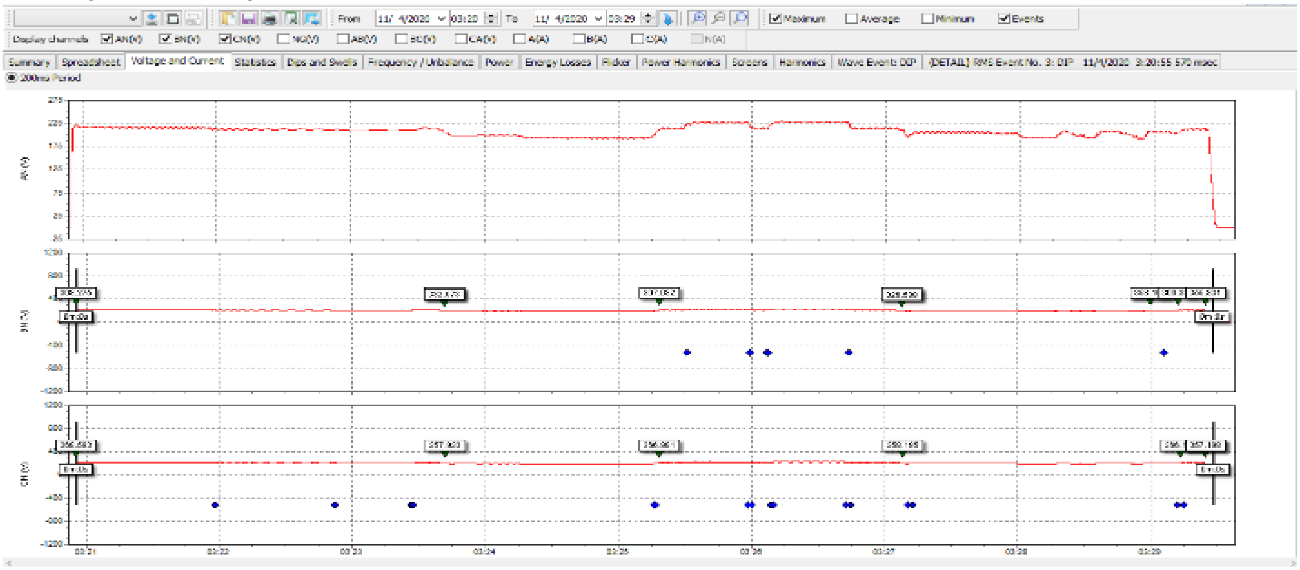

Fig. 3 Voltages of different switching of loads on wind turbine

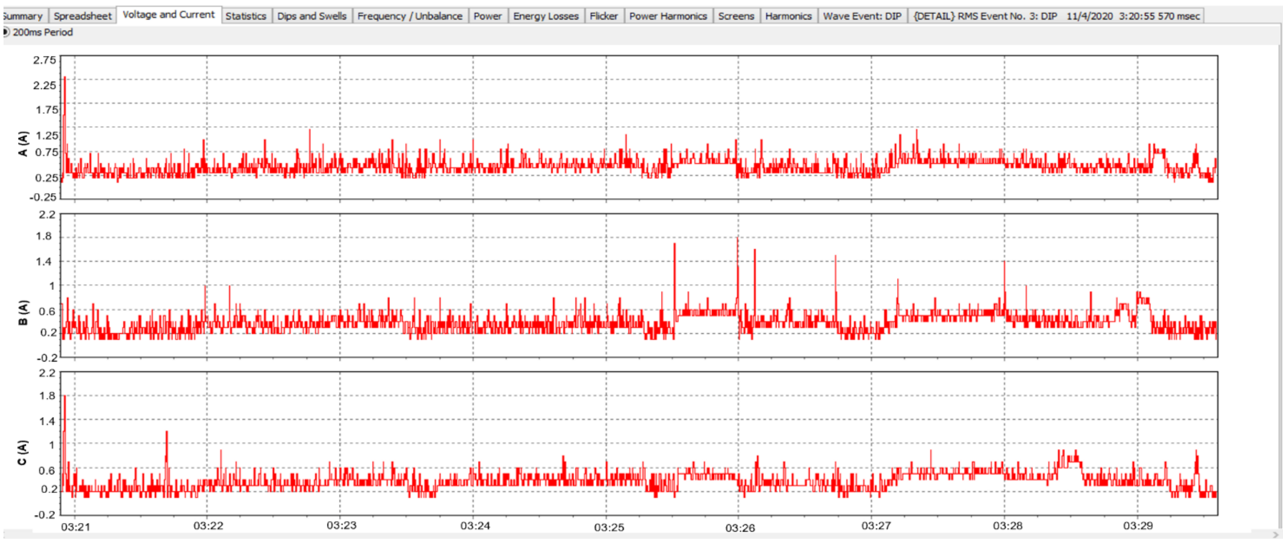

Fig. 4 Current different switching of loads on wind turbine

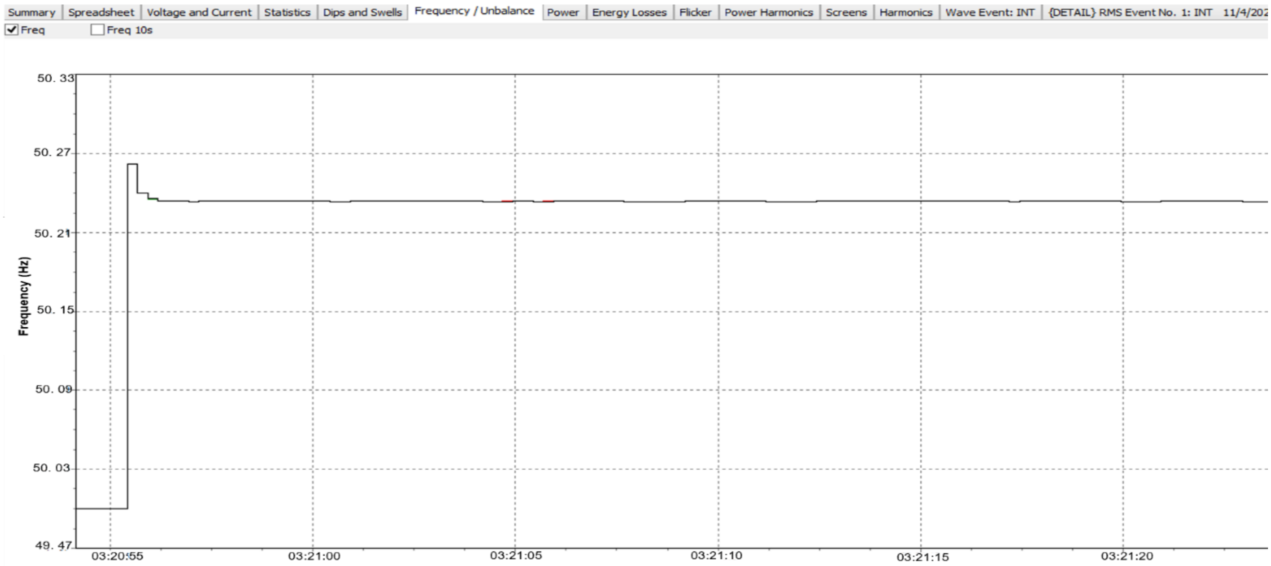

Fig. 5 Frequency unbalance while switching of R load in the wind

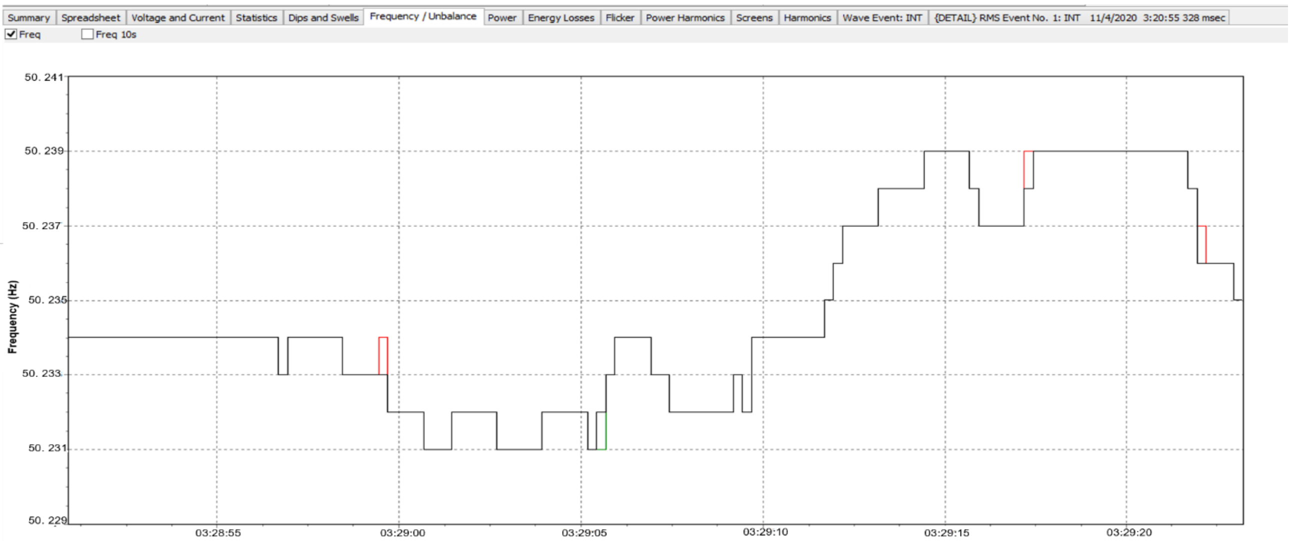

Fig. 6 Frequency unbalance while switching of C load in the wind

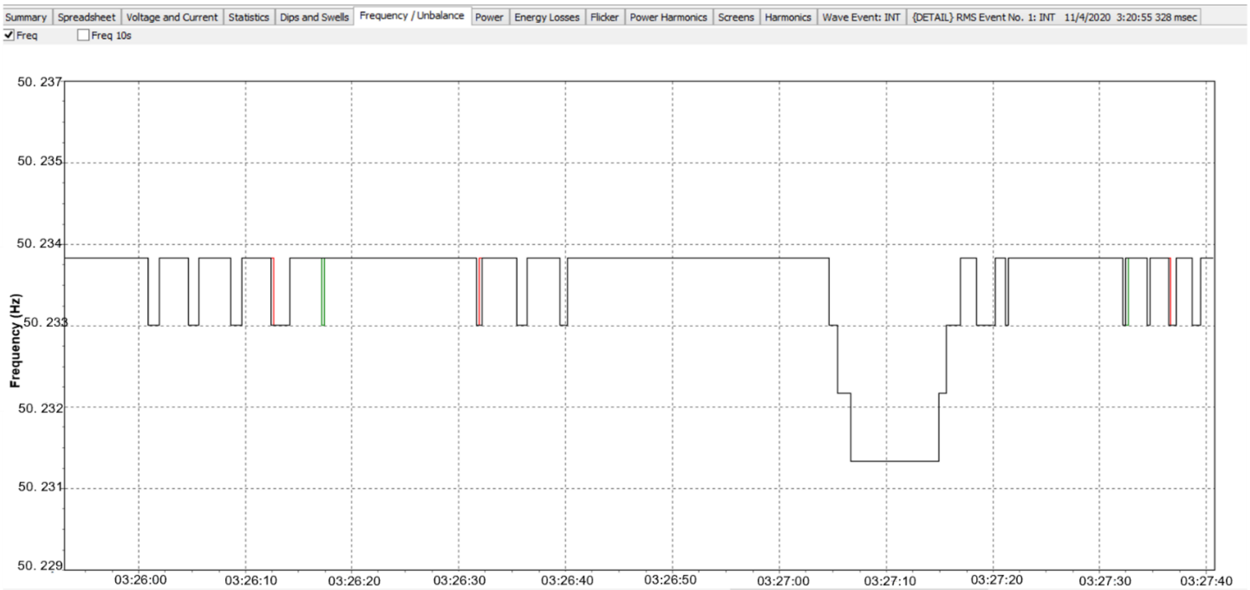

Fig. 7 Frequency unbalance while switching of L load in the wind

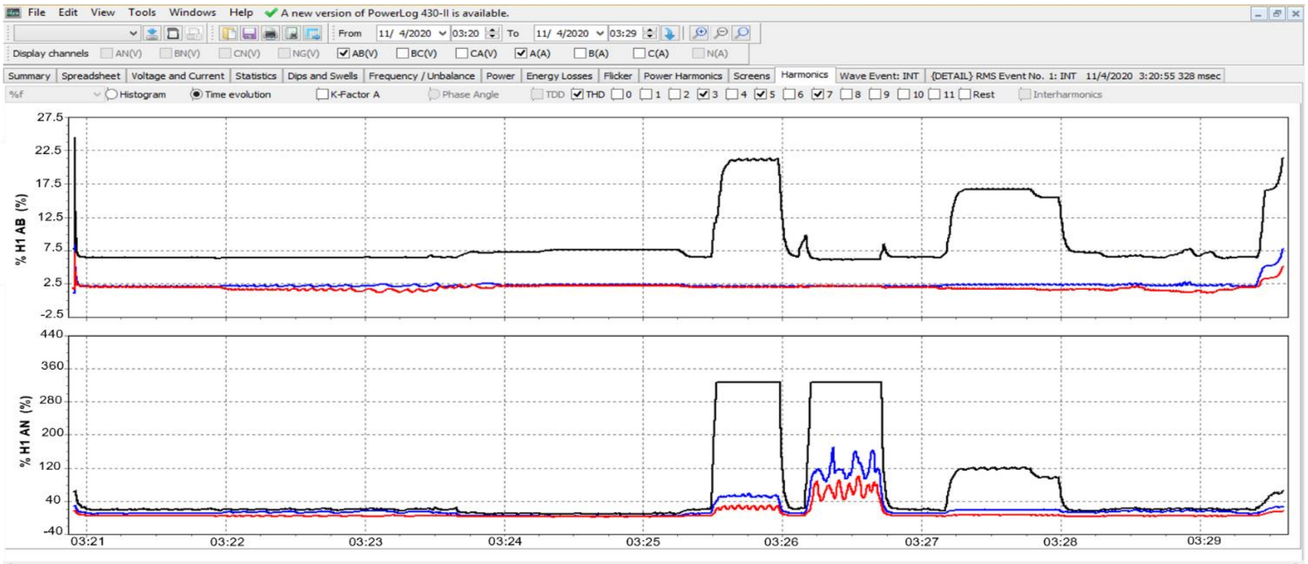

Fig. 8 V & I harmonics in wind

APPENDIX B

Results of Power Quality Issues in Solar Generation

Fig. 9 Voltages while switching of load in solar

Fig. 10 Current while switching of load in solar

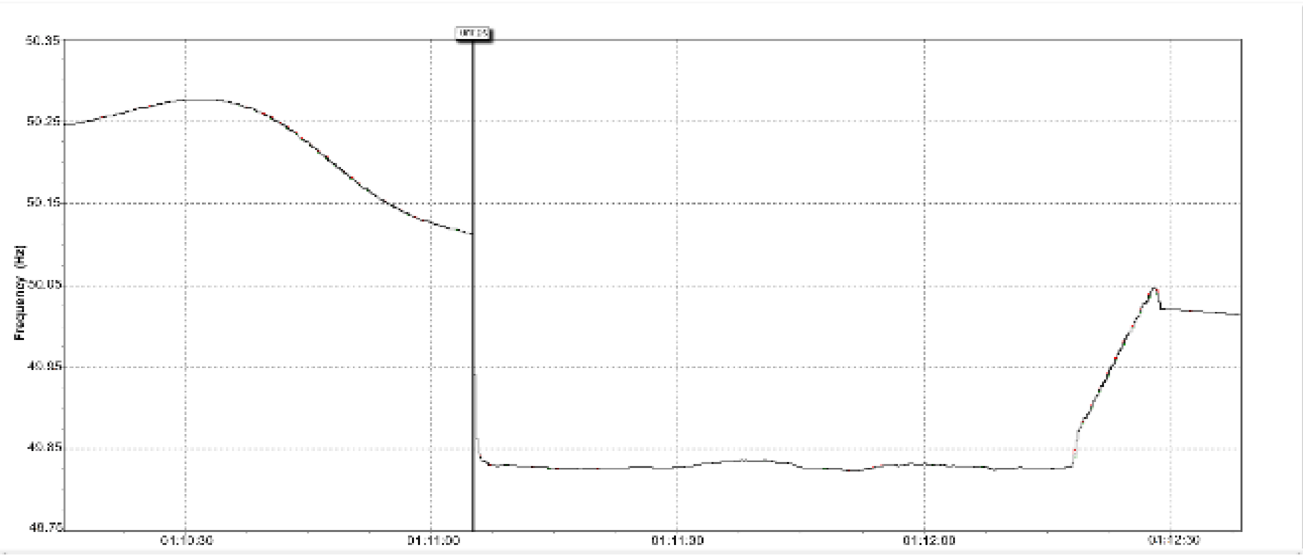

Fig. 11 F unbalance in the switching of load in solar

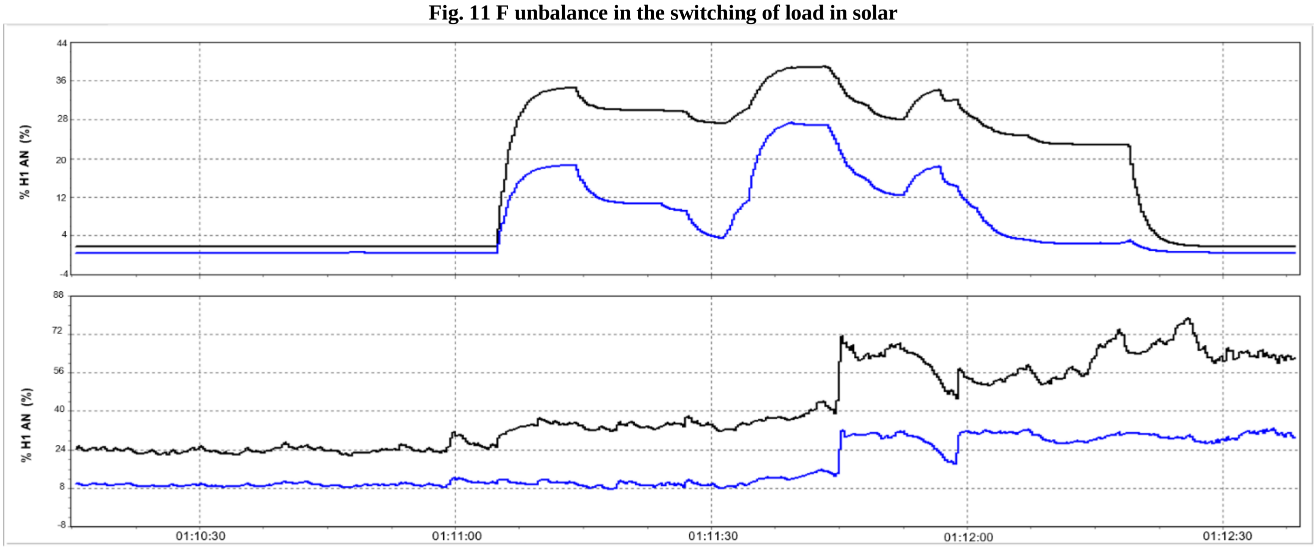

Fig. 12 V & I harmonics in solar

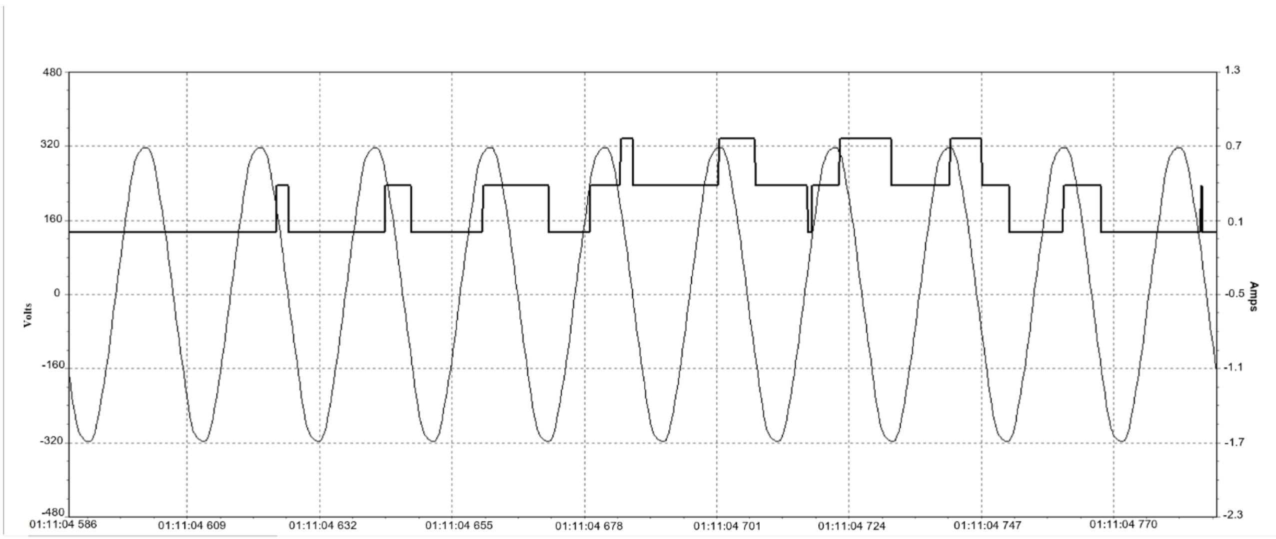

Fig. 13 V & I while switching R load in solar

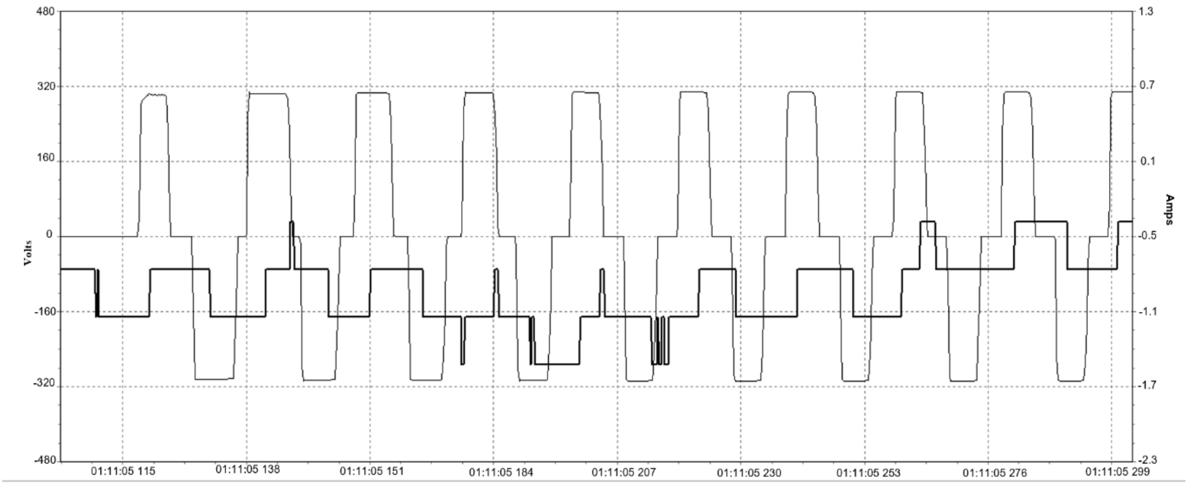

Fig. 14 V & I while switching L load in solar

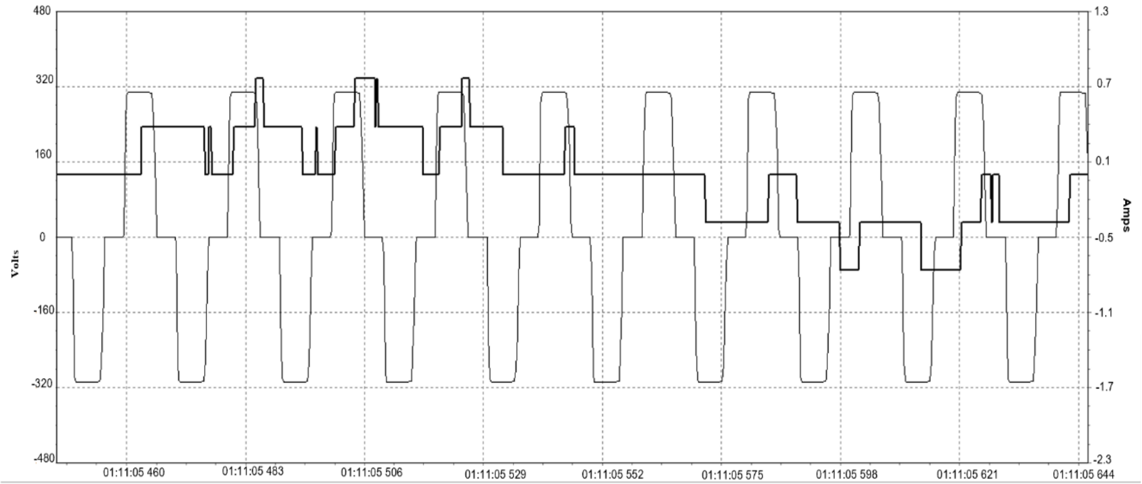

Fig. 15 V & I while switching C load in solar

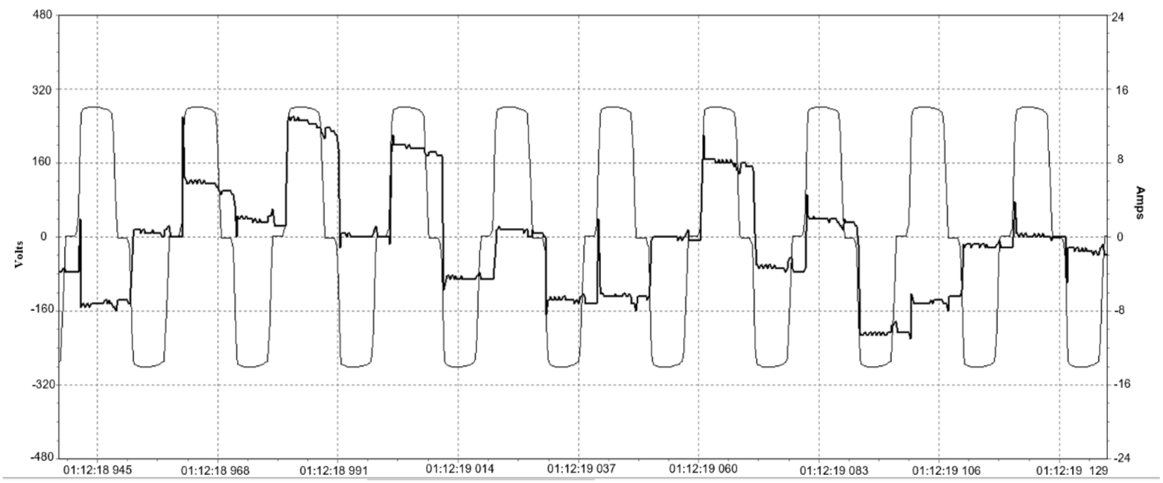

Fig. 16 V & I while switching combination of load in solar

APPENDIX C

Results of Power Quality Issues in Hybrid Generation

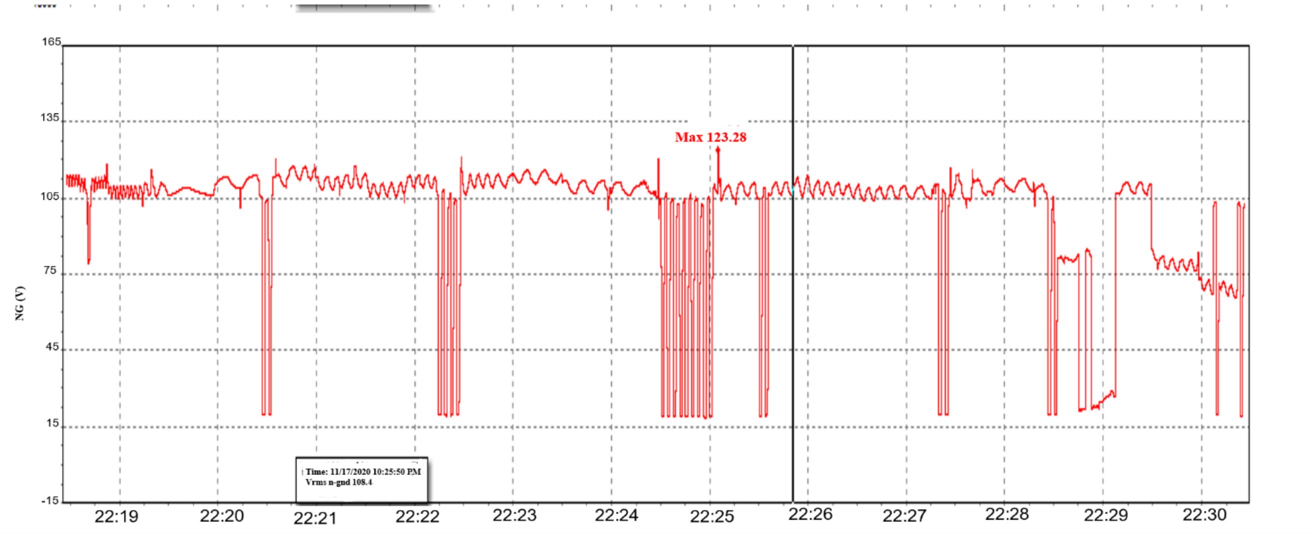

Fig. 17 Voltage waveforms in the hybrid energy system

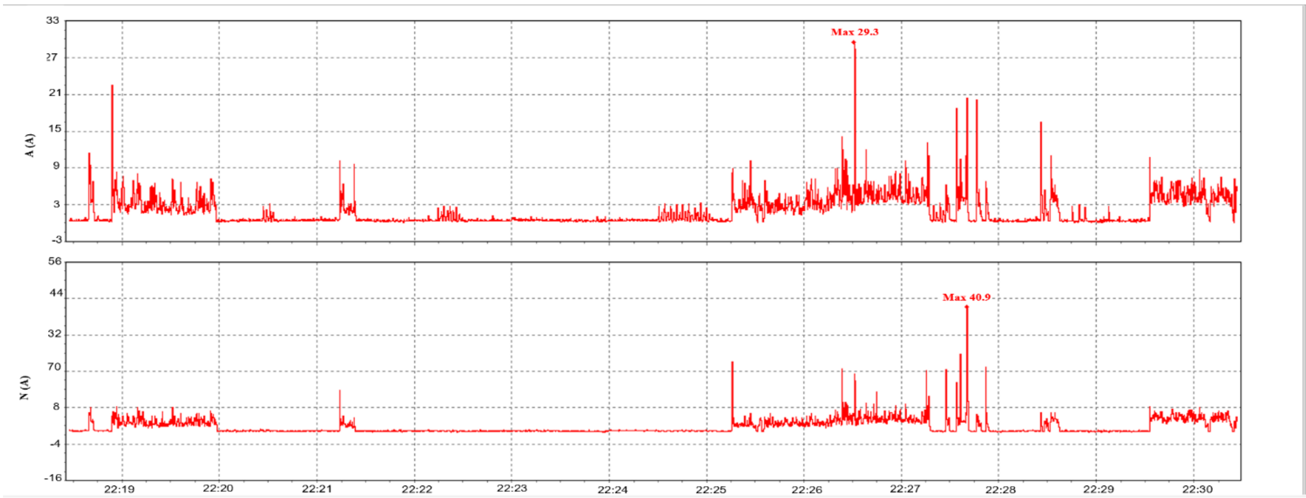

Fig. 18 Current waveforms in the hybrid energy system

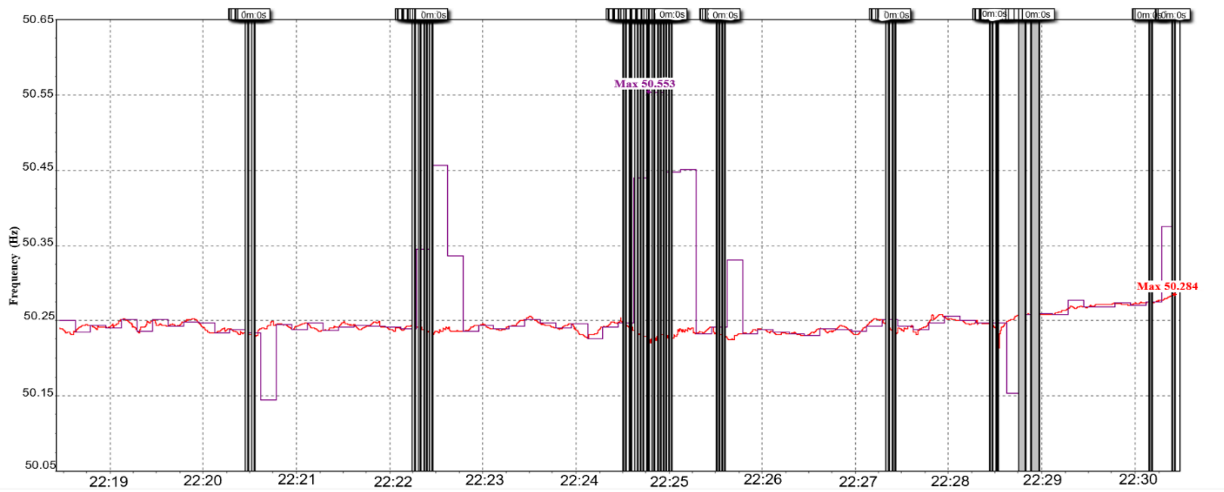

Fig. 19 Frequency unbalance in the hybrid system

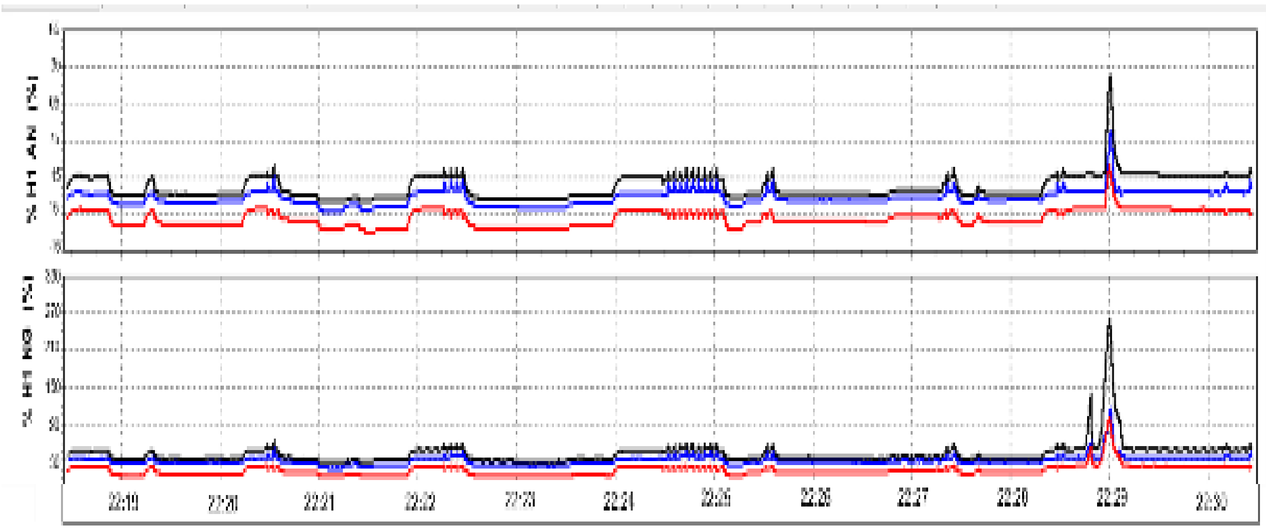

Fig. 20 V harmonics at R & L load in hybrid

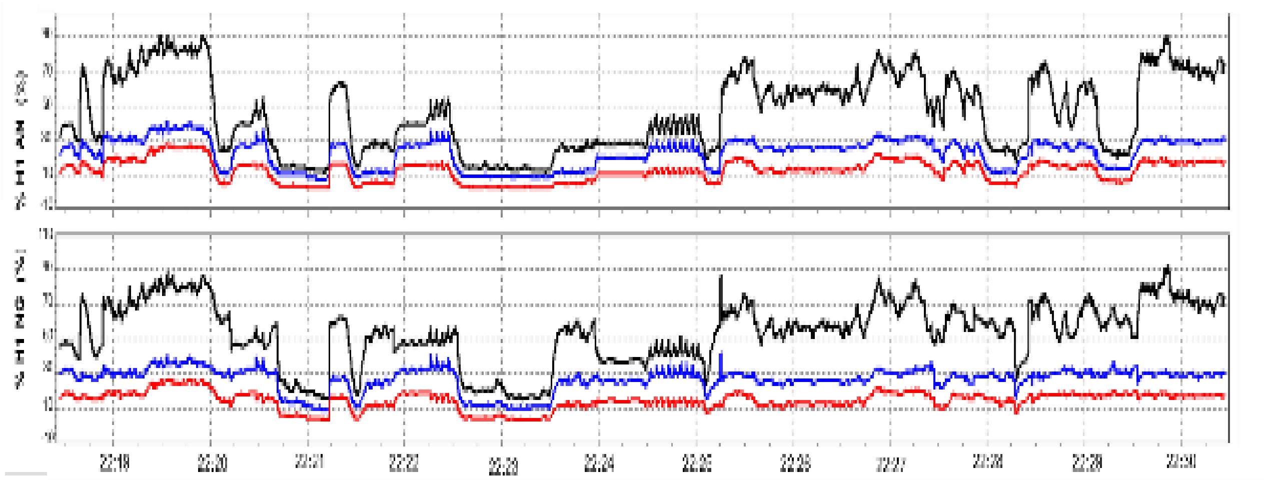

Fig. 21 I harmonics at R & L load in hybrid

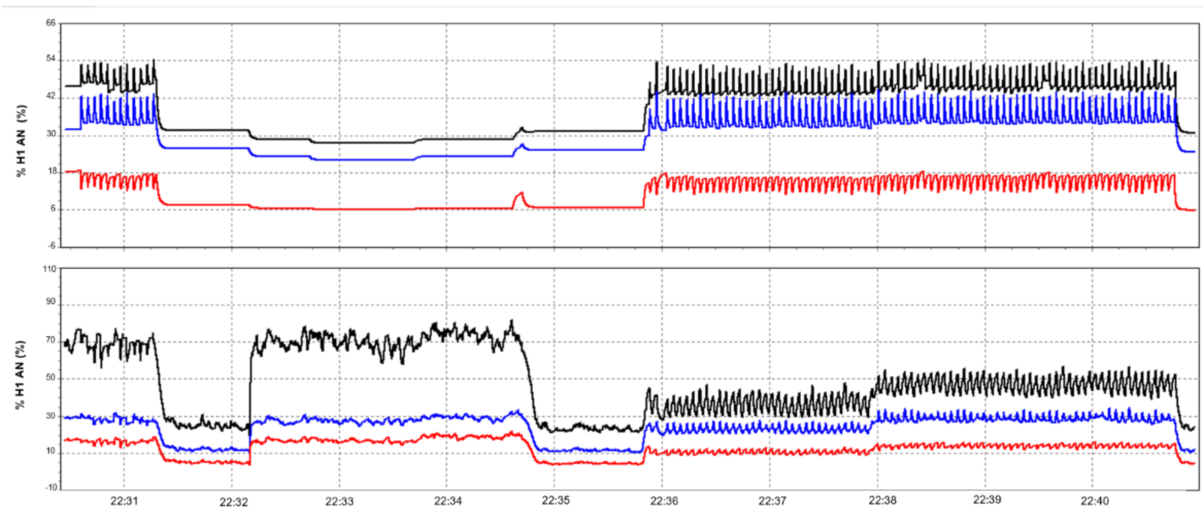

Fig. 22 Harmonics with capacitive load

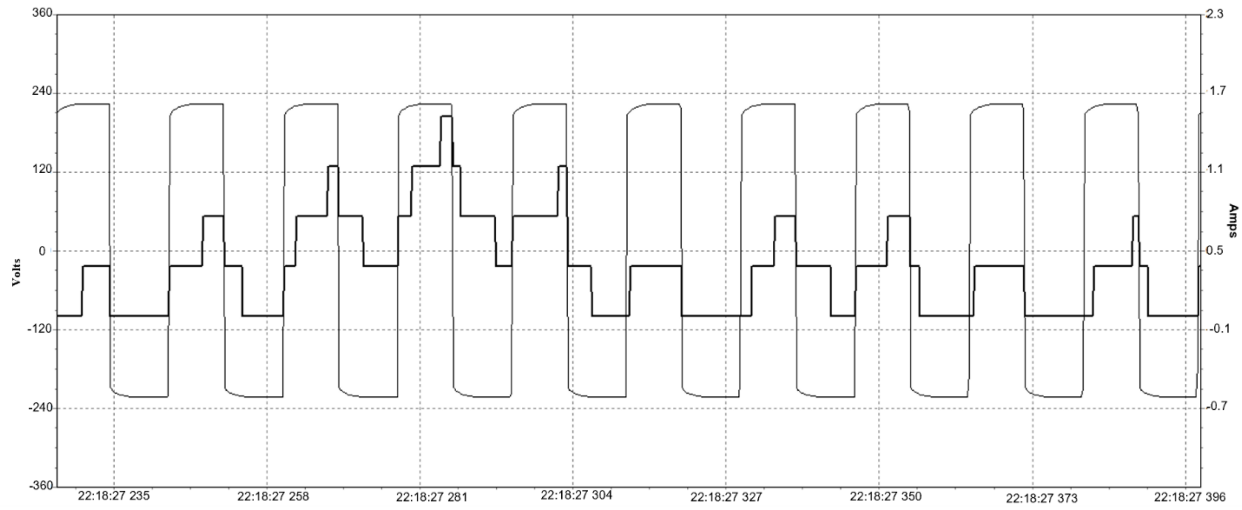

Fig. 23 Switching of resistive load in hybrid

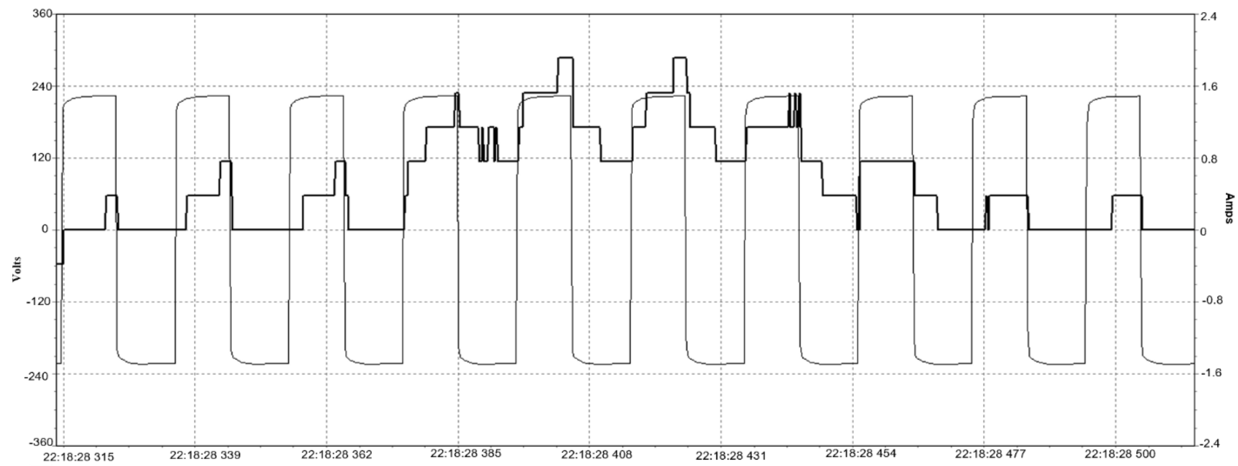

Fig. 24 Switching of L load in hybrid

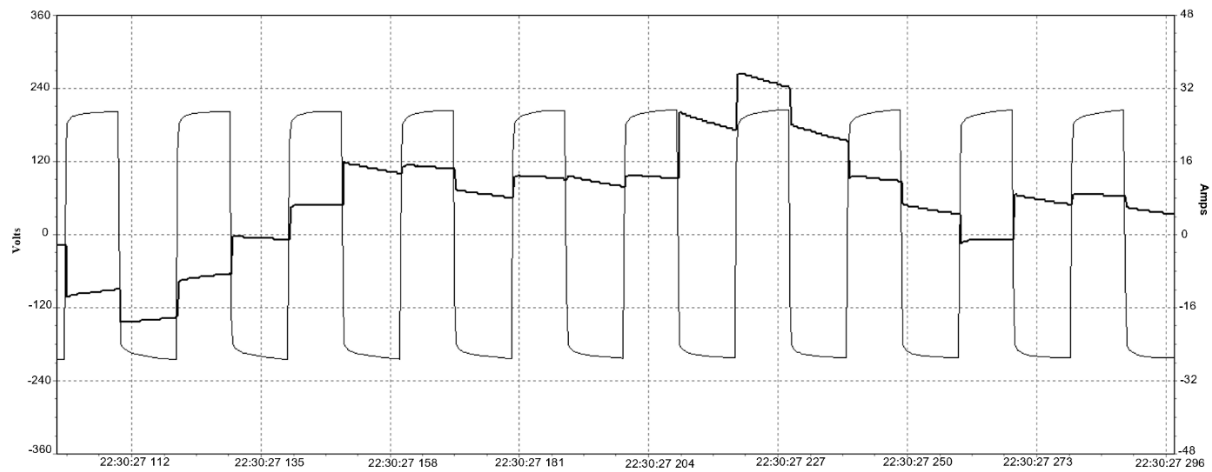

Fig. 25 Switching of C load in hybrid