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International Journal of
Electrical and Electronics Research (IJEER)
Research Article | Volume 10, Issue 2 | Pages 256-263 | e-ISSN: 2347-470X

Energy Management System and Enhancement of Power Quality with Grid Integrated Micro-Grid using Fuzzy Logic Controller

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ABSTRACT- A modern hybrid model is introduced, which is a combination of PV, Wind turbine, converter components to improve Microgrid (MG) operation, to improve system dependability, effective efficiency, which are fundamental qualities. In view of renewable energy Maximum Power Point Tracking (MPPT) is frequently applied to improve PV efficiency in which randomness, flexibility of solar energy because of changes in temperature. To achieve MPPT P&O rule, Incremental conductance (IC) methods are implemented in this manuscript. The design, execution of EMS with Fuzzy Logic Controller (FLC) for AC/DC microgrid is implemented. Apart from designing of EMS the power quality of MG is improved. It proposes analysis, control of storage devices. The FLC improves battery life and also will achieve desirable SoC. An FLC based EMS grid integrated MG is adopted, to mitigate power quality issues under nonlinear, unbalanced load conditions. The proposed model is executed by adopting MATLAB/SIMULINK.

Keywords: Microgrid, MPPT, P&O, Incremental conductance (IC), EMS, FLC

ARTICLE INFORMATION

Author(s): Himabindu Eluri, M. Gopichand Naik;
Received: 14/04/2022; **Accepted**: 27/05/2022; **Published**: 15/06/2022;
E- ISSN: 2347-470X;
Paper Id: IJEER220415;
Citation: 10.37391/ijeer.100234
Webpage-link:
https://ijeer.forexjournal.co.in/archive/volume-10/ijeer-100234.html

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1. INTRODUCTION

Renewable energy sources (RES) like PV, WIND develops their priorities to meet large demands of electricity in these modern days. The implementation of hybrid energy systems (HES) is affected by RES [1]. Solar energy, which is abundant in nature, has become necessary to meet global energy needs. The power generated by PV is fed into grid where possibility is in two ways *(a)* From grid to consumer house *(b)* From consumer house to grid. Hybrid model is integrated to make power system much powerful without disturbing regular activities of domestic sectors [2]. Wind power is another RES which produces clean electricity at fair cost. The wind energy conversion systems (WECS) are divided into two types: Constant speed WECS, Dynamic speed WECS.A constant speed WECSs are made up of a grid-connected self-excited induction generator that can be started as a motor using a soft starter and then run as a generator in grid-connected mode, with shunt capacitors supporting the reactive power requirement [3]-[4].

Operating slip of an induction generator cannot modify wind velocity due to shaft speed variations. Uncontrollable input, wind resource evaluation to extract maximum power, necessity for virtual inertia are challenges in WECS [5].

Microgrid (MG) incorporates multiple-inverter interfaced DG's which supplies local loads with active (P), reactive power (Q). Power quality issues in HES became more prominent as a result of deployment of power converter-based DistributedGenerators (DG) in MG [6].

The basic structure of EnergyManagmentSystem (EMS) is shown in *Figure 1*. To achieve MPPT P\&O rule, Incremental conductance (IC) methods are implemented in this manuscript. The design of EMS with FLC for AC/DC microgrid system is implemented. Apart from designing of EMS power quality of MG is also improved [7]-[9].

It proposes analysis, control of distributed storage devices. The FLC improves battery life and also will achieve desirable SoC.An FLC based EMS grid integrated MG is adopted and to mitigate power quality issues under nonlinear, unbalanced load conditions. To improve power quality THD is key factor and THD can be reduced by adopting proposed system [10]. The proposed model is implemented by using MATLAB/SIMULINK. *Section 2* presents MPPT methods, *Section 3* provides control strategy of proposed system, *Section 4* gives results, *Section 5* confers conclusion.

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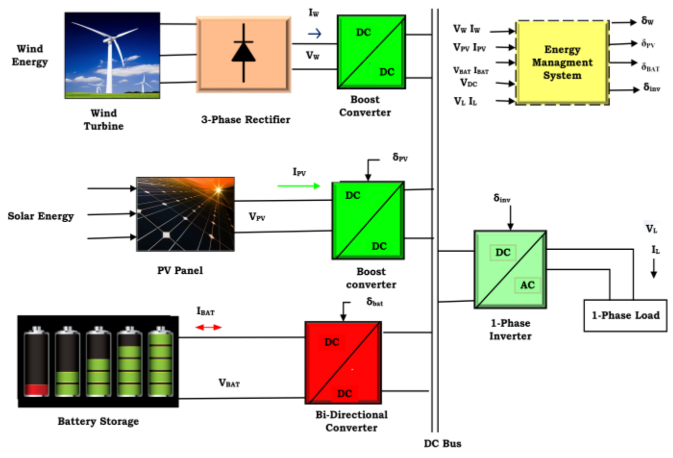

Figure 1: Basic structure of EMS

2. MPPT METHODS

2.1 Peturb & Observe (P&O) MPPT method

The P&O flowchart is shown in *figure 2*. P&O technique is adopted for tracing MPP which is simple, no requirement of former data of PV generator characteristics. Module voltage is increased or decreased to detect whether power is boosted or diminished. If an increase in voltage leads to an increase in power, PV's operating point will be too left of MPP [11]. If more disturbance is required to attain MPP, move to right. If an increase in voltage causes drop in power, indicates that PV operating point is to right of MPP [12]. P(t) is obtained with V(t), I(t), evaluated with P(t-1).If ΔP is equal to zero, MPP is obtained; however, as power increases, it is possible to constrain next voltage change to same command as preceding action[13]. Alternatively, shift the voltage in opposite direction as previous.

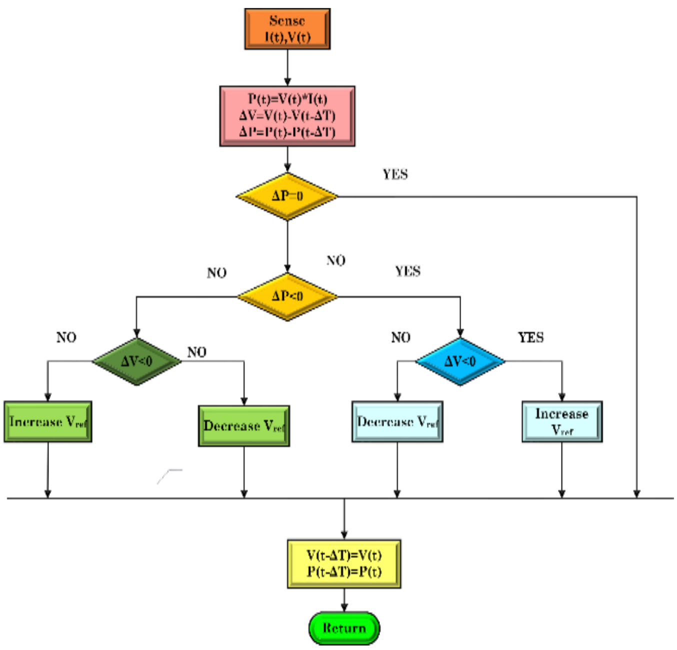

Figure 2: Flowchart for P&O MPPT method

2.2 Incremental Conductance (IC) MPPT method

The IC technique is based on idea of MPP, slope of PV array power curve is zero. On a broad irradiation changes environment, IC seeks to improve tracking time, create more energy [14]. To find appropriate operating point, the IC technique uses knowledge of source voltage, current. The MPP is tracked by comparing instantaneous conductance *I/V*, IC ΔI/ΔV. The IC raises or decrements reference until condition ΔI/ΔV = -I/V is accomplished. The PV array's operation is maintained once maximum power is reached. With high sample rates, quick power slope calculations, tracking efficiency, automatic module operating voltage adjustment with no oscillations, IC is powerful algorithm. In exchange for its implementation complexity, oscillation around MPP area can also be suppressed. The voltage increase, decrement was chosen manually by trial, error, therefore tracking time was still slow. The reaction has been improved, ability to manage extracted power has been established [15]. The flow chart of IC is shown in *figure 3*.

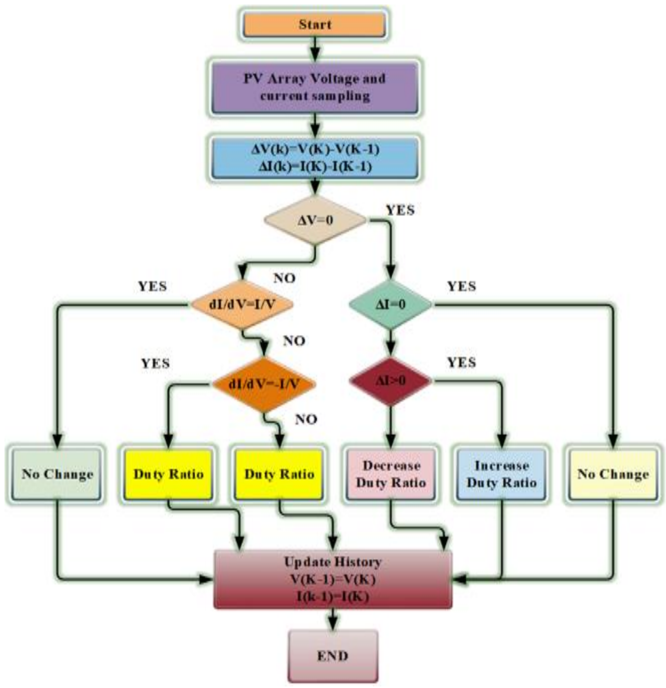

Figure 3: Flowchart for IC MPPT method

3. POWER QUALITY ISSUES AND CONTROL STRATEGY

Even when nonlinear/asymmetrical loads are coherented, introducing sinusoidal current into grid is a key unbiased component of improving power quality [16]-[18]. Due to existence of both non-linear, unbalanced loads, which make up a larger proportion of the overall microgrid load, power quality is a major concern in small-scale island or monovalent MG. In a relatively weak system, this scenario causes voltage difficulties like distortion, fluctuation, sags/swells. To reduce harmonics in both voltages, current FLC is implemented. The control strategy FLC adopted in this manuscript is associated with battery storage systems This EMS FLC methodology is

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robust control method is intended voltage stability, dynamic response of islanded MG [19]. The FLC is applied because of cheaper, reliable, is designed to reduce time of calculations. The FLC acknowledges load demand can meet both technical criteria, economic criteria [20]. This paper presents EMS for effective mitigation of grid power profile fluctuations [12]. The above proposed EMS incorporates low complexity FLC with 25 rules which will develop SoC of battery. This approach is based on monitoring of rate of change of energy, SoC of battery which controls power delivered/absorbed by grid. The proposed control strategy is shown in *figure 4*.

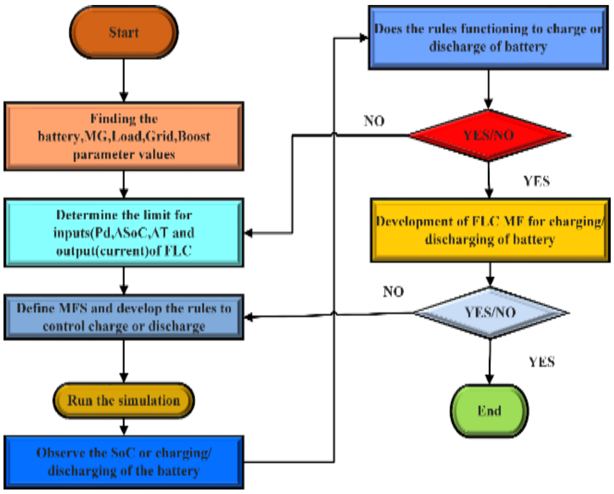


Figure 4: Flowchart for FLC

For FLC based EMS the architecture is divided into three types:

• The FLC is designed to control charging-discharging of battery, set of fuzzy rules are created to notice performance of controller.

• The algorithms which are introduced in this proposed system are to control battery charging and discharging.

• FLC based EMS is used to perform scheduling of ESS, battery of MG.

The proposed FLC is shown in *figure 5*. The power flow is done by scope of PV, load condition, SOC of battery. The proposed FLC has two input membership function, output membership function which is shown in *figure 6, figure 7* respectively [21]. The power flow management is done by scope of PV, load condition, SOC of battery [22]-[23]. The proposed FLC has two input membership function, one output membership function MG.

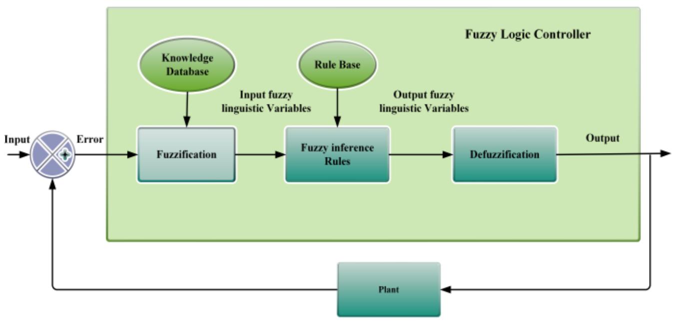
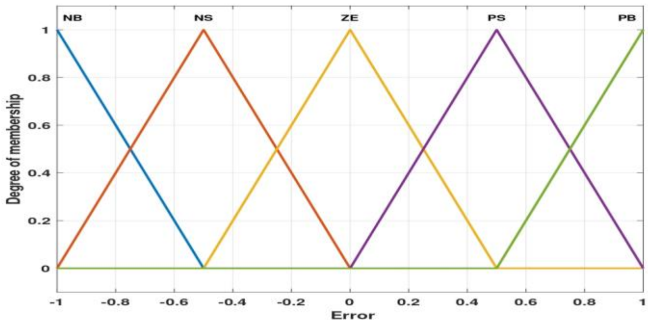
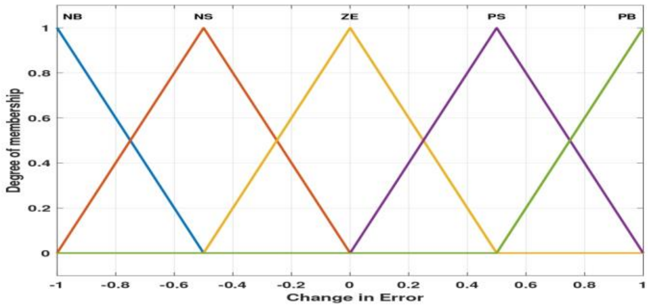


Figure 5: Proposed Fuzzy Logic Controller



(a) Membership Function for Input1



(b) Membership Function for Input2

Figure 6: Membership Function error, change in error

The output menmbershipfunction is shown below

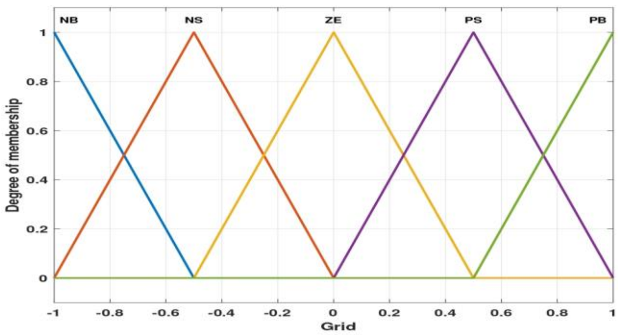


Figure 7: Output Membership Function

Table 1. Rule Table

Error/Change in Error	PS	PB	ZE	NS	NB
PB	PB	PB	PB	PS	ZE
PS	PB	PB	PS	ZE	NS
ZE	PS	PB	ZE	NS	NB
NS	ZE	PS	NS	NB	NB
NB	NS	ZE	NB	NB	NB

4. RESULTS

The simulation results are explained in this section. This result includes Grid, PV voltage, EMS system with PI, FLC, shown variations in results of THD for Vs, Is, VL, IL with PI, FLC.In this manuscript EMS is noted in two conditions.

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Condition 1: Grid is 'ON', Battery is 'OFF'; Condition 2: Grid is 'OFF', Battery is 'ON.

This idea improves RES capability, efficiency of major grids. The *figure 8* depicts proposed micro grid's final results without and with EMS. With EMS, controller controls power efficiently via switching events. When grid is switched on, battery is turned off, loads are turned on as required. The powers with EMS are represented in Figure 8. By using an efficient controller, the grid power reached a steady state in the shortest period possible, 0.03 seconds. The transient period is reduced by controller. After 4 seconds, battery begins to charge. Load1 is turned on at 1sec, load1 transients are minimized at 1.003sec.

The transients occur at 4sec and are removed at 4.03sec, bringing load power1 to a stable state, whereas load2 is switched on at 3sec, transients occur at 4sec, bringing load power2 to a stable state at 4.02 sec. *Figure 9* depicts use of FLC to manage active, reactive power as well as battery power, load powers. *Figures 10* depicts variation of grid, PV voltage, current, power and SoC respectively. The comparison of DC voltage regulation using PI, proposed controller, is shown in *figure 12, figure 13* respectively. *Figure 14* shows the improved %SoC with FLC. It is observed that \%SoC improved from 78.8% to 84.5% within permissible time compared to PI controller, battery parameters are improved. *figure 15* shows that results of compensated source voltage, *figure 16* indicates that simulation results of proposed control strategy along with compensated device injects voltage from phase to load voltage as well as phase to load current. The THD values of all mitigating parameters is shown in *figure 17* to *figure 24* respectively.

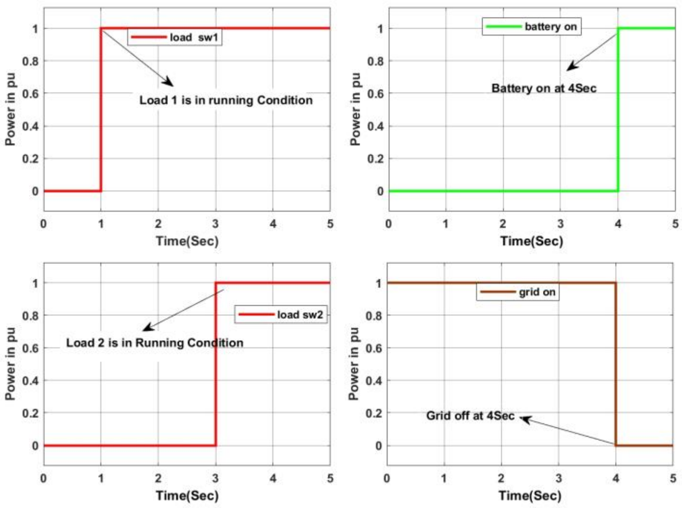

Figure 8: Simulation Results of EMS under different operating conditions with FLC

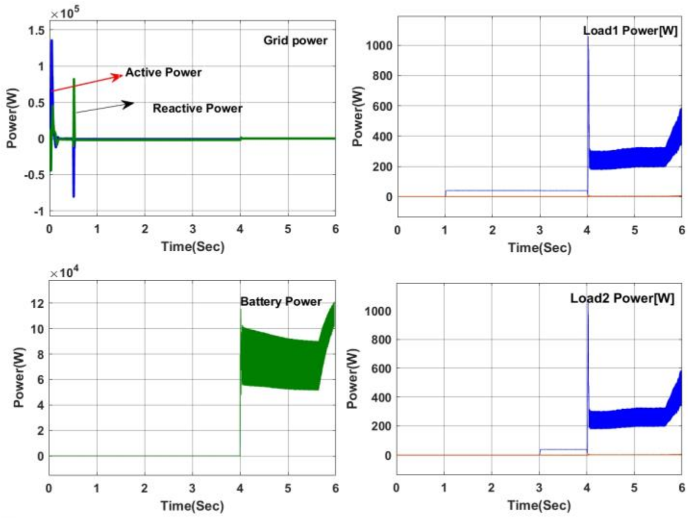

Figure 9: Simulation Results of Grid, Battery, load power

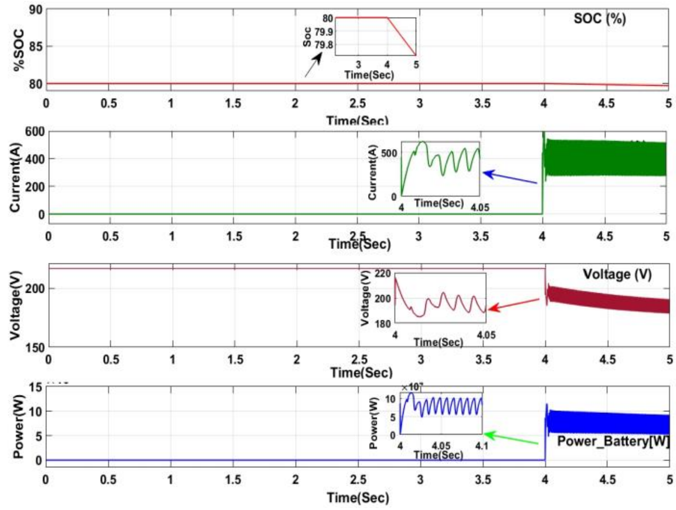

Figure 10: Results of Power and SoC

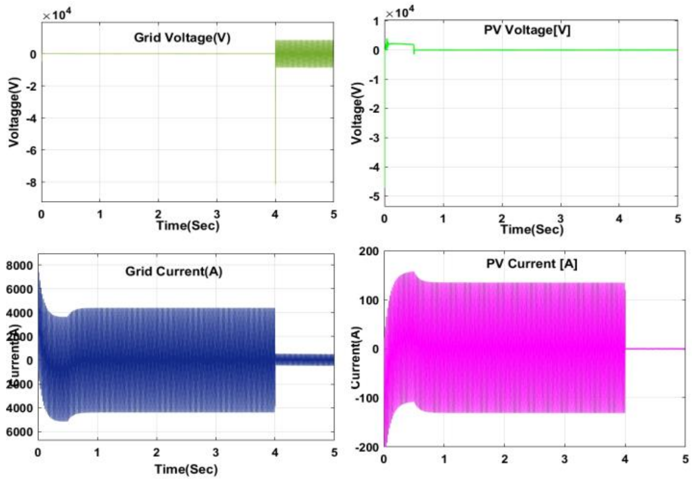

Figure 11: Simulation of Grid, PV Voltage, Current

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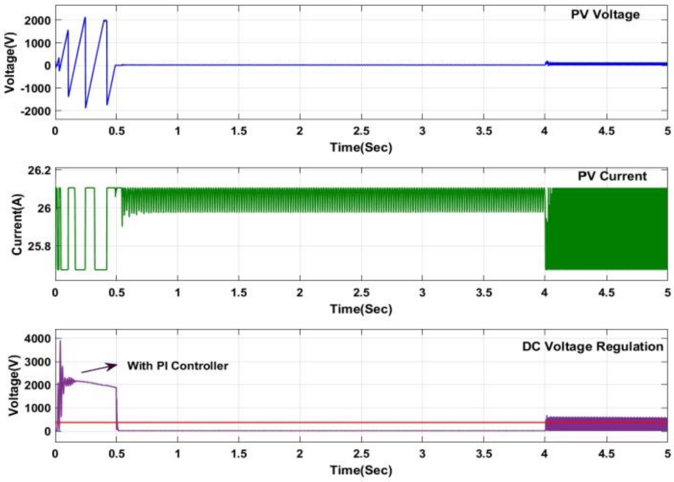

Figure 12: Results of V_{PV}, I_{PV} DC Voltage regulation with PI

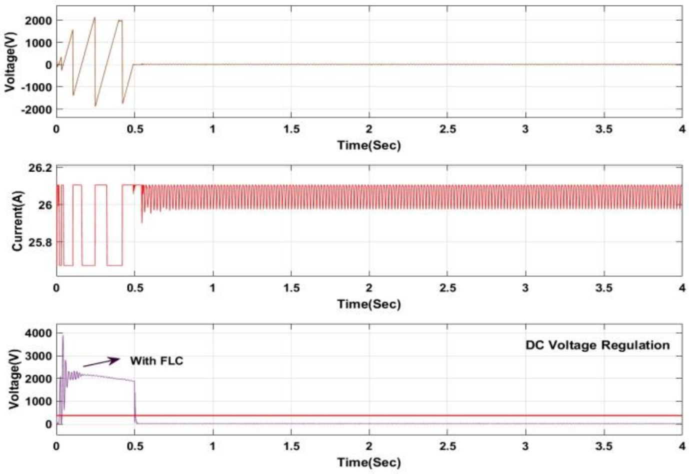

Figure 13: Results of V_{PV}, I_{PV} DC Voltage regulation with FLC

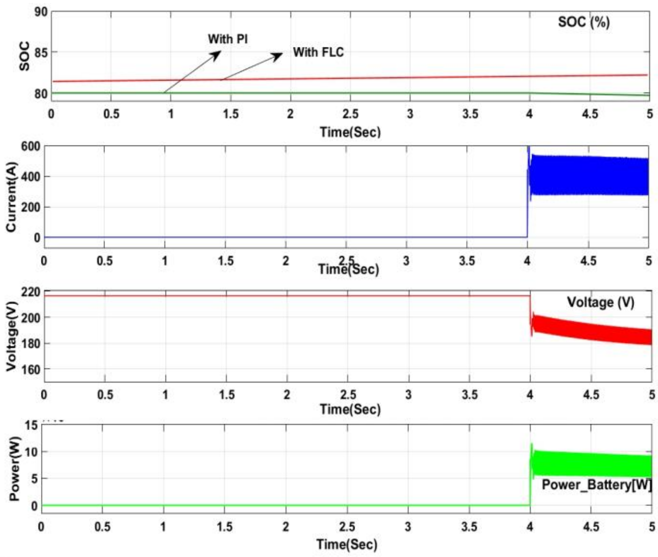

Figure 14: Results of battery management systems includes %SoC, Voltage, Current and battery

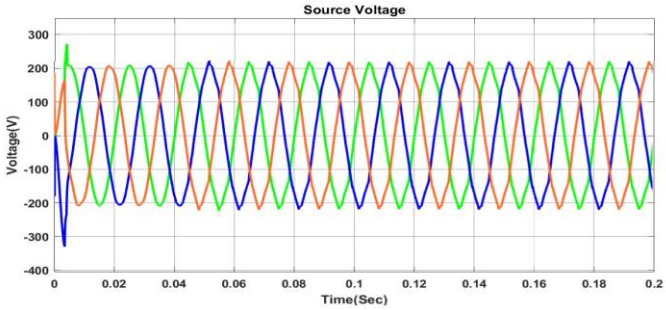

Figure 15: Simulation Results of Source Voltage

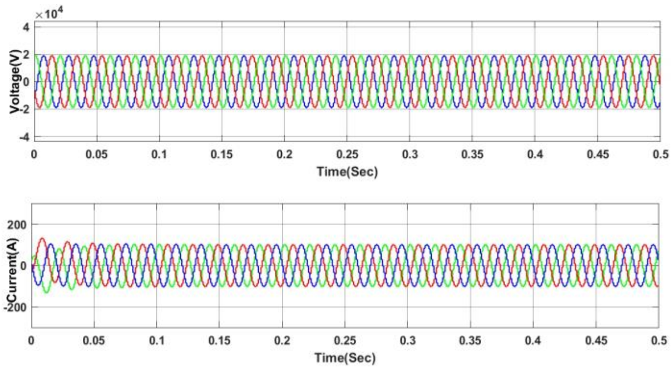

Figure 16: Results of Load Voltage, Load current

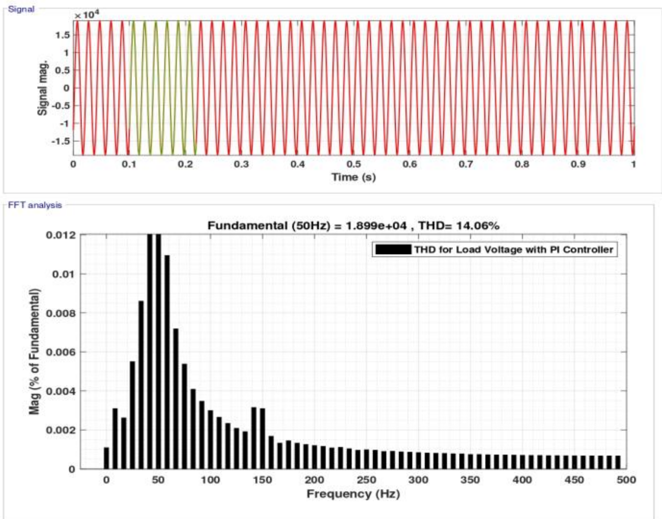

Figure 17: THD for V_L with PI

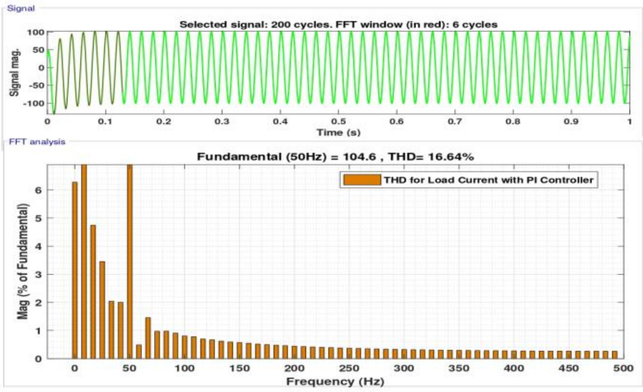

Figure 18: THD for I_L with PI

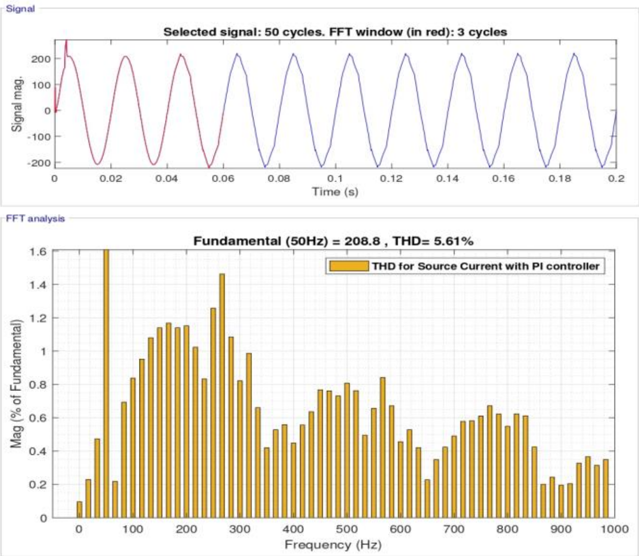

Figure 19: THD for I_s with PI

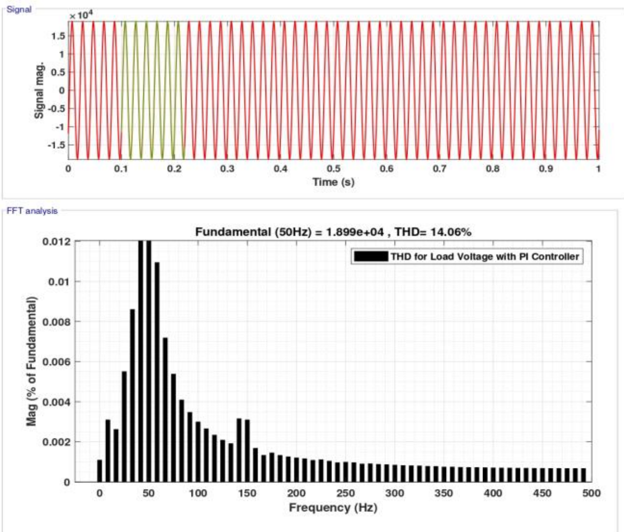

Figure 20: THD for V_s with PI

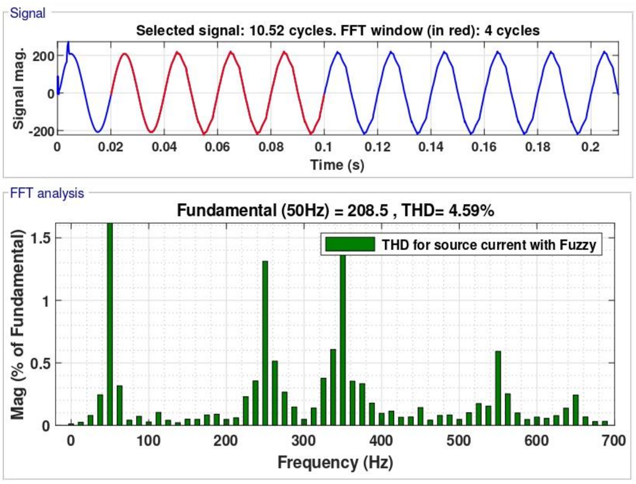

Figure 21: THD for I_s with FLC

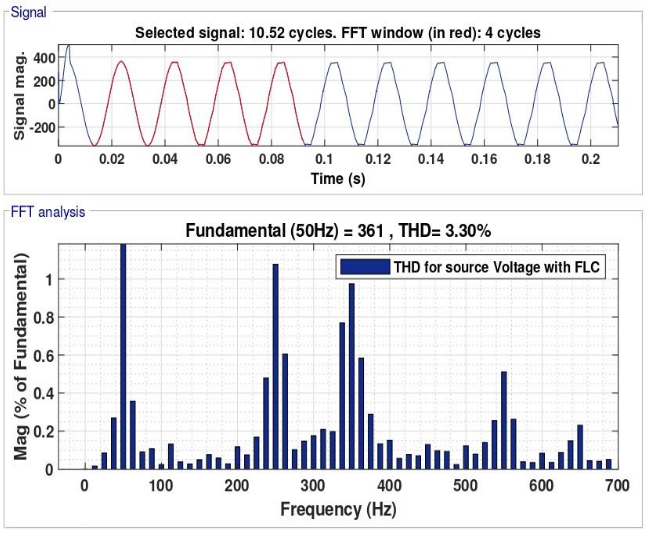

Figure 22: THD for V_s with FLC

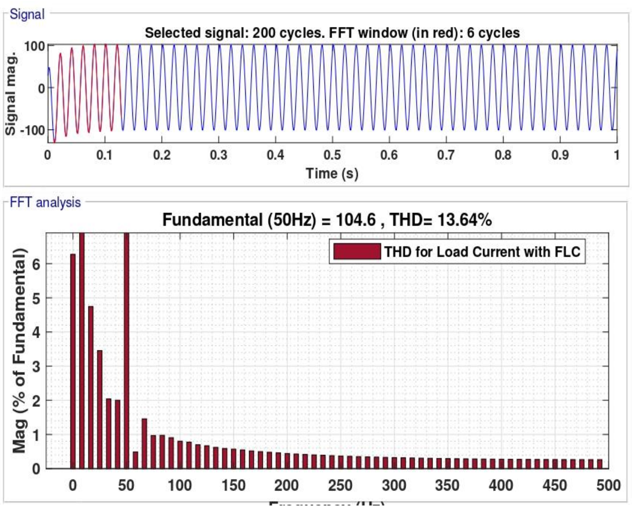

Figure 23: THD for I_L with FLC

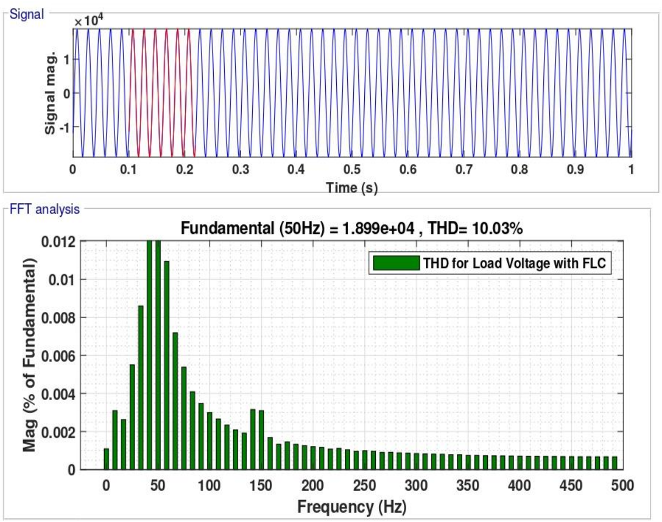

Figure 24: THD for V_L with FLC

The comparative analysis in this manuscript is for proposed EMS is done for both PI and FLC controller. This analysis is done for both source current, load current and also for source voltage, load voltage by implementing PI controller, intelligent controller like FLC.The DC regulation is improved by adopting FLC. By adopting FLC THD of Is is reduced to 4.59% from 5.61%, THD of IL is reduced to 13.64% from 16.64%, THD of Vs is reduced to 3.30% from 6.30%, THD of VL is reduced to 10.03% from 14.06%. These results are tabulated in *Table 2*.

Table 2. Comparative analysis of THD with PI, FLC

S.No	Controller	THD for I_s	THD for I_L	THD for V_s	THD for V_L
1	PI	5.61%	16.64%	6.30%	14.06%
2	FLC	4.59%	13.64%	3.30%	10.03%

5. CONCLUSION AND FUTURE WORK

FLC-based EMS is designed for integrated micro-grid is connected to distribution power systems using MATLAB/SIMULINK. The advantages of EMS are to improve reliability by applying suitable FLC. The result shows that transition period is shortened. The secondary objective is efficiency of energy management system. Third objective is monitoring of MPP point that is carried out with MPPT algorithm. In this paper FLC, based energy management systems, to track MPPT. P&O, IC methods are developed, to enhance power quality, reduction of THD in micro-grids. It is observed that power quality issues mitigated using FLC Controller. The results show that THD values of source voltage is 3.30%, source current THD is 4.59% with FLC. The future scope of proposed work can adopt fractional order PI, Fractional order Fuzzy logic controller to reduce percentage of harmonics in both source voltage, load voltage, source current, and load current.

6. ACKNOWLEDGMENTS

This manuscript research behind it would not have been possible without exceptional support of my supervisor Dr.M. Gopichand Naik who is professor in department of EEE, Andhra University. His enthusiasm, knowledge and exacting attention to detail have been an inspiration and kept my work on track.

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