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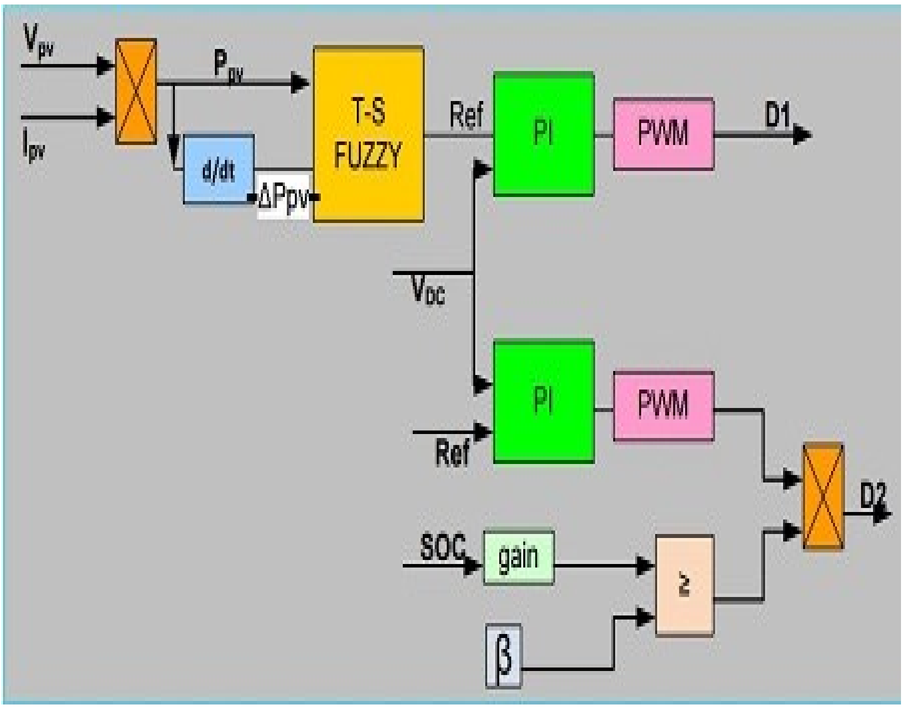

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Editorial

Second Year with "Turkish Journal of Electromechanics & Energy"

"From the North of Turkey to the World"

2017

We are happy to meet you again to present our second volume of Turkish Journal of Electromechanics & Energy (TJEE). Each volume and issue bring new joy and excitement to us as the journal is in its crawling stage. We appreciate our authors, reviewers and editorial board members for their contribution in realizing this issue.

The current issue of the TJEE (Vol 2. No:1 January-June 2017) consists of two articles. These articles present original studies from mechanical and electrical engineering fields as our journal intended to provide research results from across the disciplines.

First study by Siyambaş et al. investigated the effect of cutting parameters on the diameter deviation in drilling of high strength low alloy (HSLA) material. TiAlN coated and uncoated drills were used in experiments. Effect of feed rates and cutting speed on the results were also discussed.

In the second study, a new technique for enhancing the dynamic performance of a conventional proportional integral (PI) controller was used to achieve faster and ripple-free maximum power point tracking (MPPT) for standalone hybrid photovoltaic (PV) systems by Ebrahim et al.

Main motivation in establishing TJEE was to disseminate the knowledge free-of-charge for readers, and therefore we want to follow open-access way. This will not only facilitate dissemination of results in an easier and faster way but also improve referability of works. While striving to follow our way among some 35.000 journals worldwide [1], there are tremendous number of issues we need to take care of. Ethical issues, for example, are of great importance during first-evaluation of submitted manuscripts. Each manuscript goes through plagiarism check before it is directed to subject editors and then reviewers. Nevertheless, the plagiarism softwares are not flawless, and therefore we highly depend on the expertise of our reviewers and subject editors.

As we go through our second year, we plan TJEE to be indexed in respected databases. Among the other near-future plans, publishing a special issue with selected papers from some respected conferences is included. Thus, we encourage potential authors to submit their valuable works to be considered for publication in TJEE.

We consider "Publish or perish" motto as respecting every effort in science and believing the importance of recording it rather than competition and tool for author's careers development only.

Finally, we would like to hear from you. You can send your suggestions, and requests to editors.tjee@gmail.com .

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Investigation of the Effects of Cutting Parameters on Diameter Deviation in Drilling of HSLA Steel

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ABSTRACT In this study, effect of cutting parameters on the diameter deviation was experimentally investigated in drilling of high strength low alloy (HSLA) material. In the experiments, TiAlN coated and uncoated drills with a diameter of 8 mm and 130 ° point and 30 ° helix angle were used. Three different feed rates (0.05-0.075-0.1 mm / rev) and cutting speed (10-26-42 m / min) were determined as cutting parameters. As a result of the study, it was found that in the experiments with both cutting tools, the diameter deviation increases with the increase of the feed rate and cutting speed and the TiAlN coated drills perform better than the uncoated drills.

Keywords: Drilling, HSLA, Diameter Deviation, ANOVA

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1. INTRODUCTION

High-strength low-alloy (HSLA) steels are defined by microstructures formed by hard martensite particles distributed in the ductile ferrite matrix [1-2]. These steels are compared to dual phase steels due to their behavior of constant flow, high deformation hardening, high malleability, and the opportunity of obtaining good surface quality [3-4]. These materials contribute to rigidity and strength and reduction of weight without losing strength, and therefore are preferred in automotive industry. As their formability characteristics are good, they play an effective role in production of parts in vehicles such as suspension systems, support elements, longitudinal girders, cross and chassis components [5-6].

Drilling, on the other hand, is one of the most frequently used processes in manufacturing and it constitutes approximately 33% of machining [7-8]. Additionally, 25% of the entire manufacturing process consists of drilling [9]. Drilling is usually the last of the machining processes and it has great importance in economical nature of production [10]. In comparison to turning and milling processes, it has similar kinematics and dynamic structure and the debris flow, cutting temperature, weight distribution are similar in the time of cutting. However, the occurrence of debris in the process of drilling in an enclosed environment makes debris management more difficult. The thickness of debris that is formed on the drill is the factor that affects debris flow. The main problem in drilling is that the surface temperature that occurs on the surface based on friction between the drill and the material is insufficient and the cutting speed in the rotation axis is zero. Thus, there are various attempts in the literature regarding with improvements of surface coating processes, drill geometry and materials [9-11].

Developments in machining have resulted in improvements in cutting speeds and feed rates, usage of various materials in production, machine tools and tool sets. The cutting characteristics of HSS tools have been improved to a significant extent nowadays. Optimal combinations of alloying elements of cutting tools and heat processes contributed not only to optimal hardness and toughness, but also give increase in abrasion resistance [12]. One of the most important technological advantages in developing modern cutting tools is the hard coatings applied on cutting tools [13]. Coatings on cutting tools play an important role in increasing their abrasion resistance by reducing the friction on the surface between the cutting tool and chip [14].

In machining, obtaining desired surface quality in drilling processes is one of the most important issues. It is very difficult to achieve measurement accuracy on a hole drilled with a drill directly. Due to these issues, it is generally popular to use boring and reaming as secondary processes [15]. Nevertheless, a secondary process to be applied on the material leads to increases in cost. Accordingly, it is crucial for a hole to be drilled in one operation for the desired measurement accuracy. It was seen that most of the studies in the literature are dedicated to hole surface quality and measurement accuracy (deviation from diameter, circularity and cylindricality). Özkul et al. promoted usage of low cutting speeds for optimal values of diameter deviation and circularity while drilling hot work steels with reamed and carbide drills [16], while Yağmur et al. [17] suggested using low cutting speeds in drilling AISI 1050 steel with TiN/TiAlN/TiCN multi-layer coated and non-coated carbide drills to minimize vibrations, and they stated that cutting forces of coated tools are reduced due to reduced friction, and therefore, lower values of deviation from circularity may be achieved. Kıvak et al. [18], investigated the drilling of AISI 316 stainless steel with HSS drills processed with different coating operations (one-layer TiN and TiAlN, and multi-layer TiAlN/TiN), and they stated that cutting speed is a more effective factor than progression. In addition, they noted that drills coated with TiAlN/TiN had a better performance than those with other coating processes. Moreover, other studies have been conducted, where hole measurement sensitivity could be estimated based on cutting parameters, and mathematical modelling and statistical methods were used [19-20]. Furthermore, the literature also contains studies on the effects of drill diameters [21] and workpiece materials [22-23] on the hole measurement sensitivity.

In this study investigated the effects of cutting parameters on deviation from hole circularity was investigated using three different feed rates (0.05-0.075-0.1 mm/rev) and cutting speeds (10-26-42 m/min) while drilling HSLA material with TiAlN coated and uncoated HSS drills.

2. MATERIAL AND METHOD

The drilling experiments were carried out at Johnford VMC 850 CNC vertical machining center which has a capacity of 6.000 rev/min and 7.5 kW power. As cutting tools, TiA1N coated and uncoated HSS drills were acquired from Walter Corp. (Tübingen, Germany) were used. Technical characteristics of the drills used in the experiments are given in Table 1.

Table 1. Technical characteristics of cutting tools used in experiments

Cutting Tool	Coating type	Coating thickness (μm)	Number of flutes	Point angle	Helix angle	Helix length (mm)	Cutting tool image
Uncoated HSS tool	-	-	2	130º	30º	24	
Coated HSS tool	TiAlN	3	2	130º	30º	24	

As the workspace, HSLA-DIN EN 10149 high-strength low-alloy material, which is widely used in the automotive industry, was used. The chemical composition and physical characteristics of the material used in the experiments are given in Table 2 and Table 3, respectively [24].

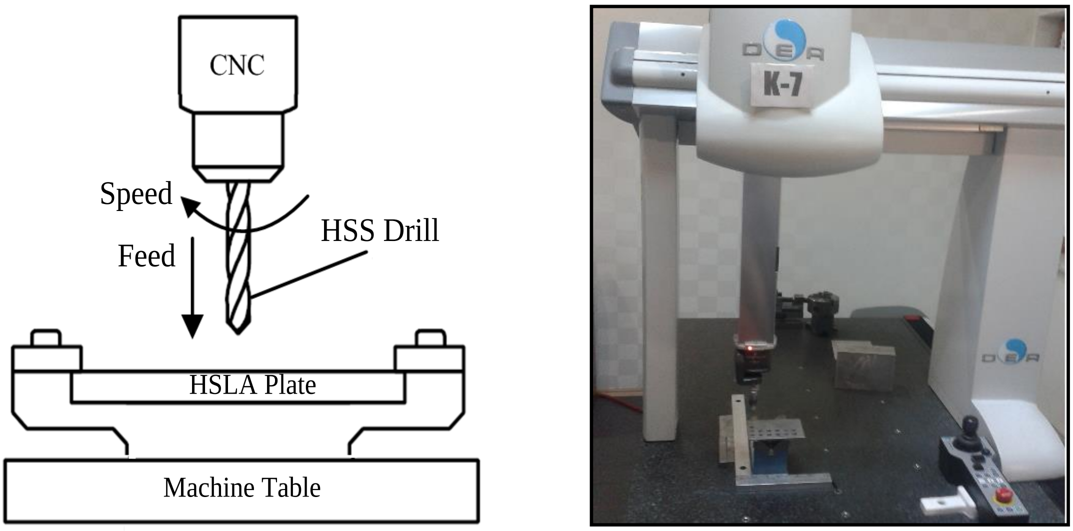
Table 2. Chemical composition of HSLA material (% max.)

C	Si	Mn	P	S	Al	Nb	Ti	V	Fe
0.12	0.50	1.50	0.025	0.020	0.015	0.09	0.15	0.20	Other

Table 3. Physical properties of HSLA material

Tensile strength (N/mm^2)	Yield strength (N/mm^2)	Elongation (%)	Pulse energy (J)	Pulse temperature (^oC)
430-550	355	23	40	-20

The drilling experiments were carried out with coolant (Hocut 3380-20% emulsion) using the set up schematic shown in Figure 1(a). Diameter deviation values were determined as arithmetic average by taking measurements from five different points via a DEA model of product (Hexagon, Germany) brand three-dimensional CMM (Coordinate Measurement Machine) device is shown in Figure 1(b).



(a) (b)

Fig. 1. a) Schematic of the experimental setup, b) View of CMM device

2.1. Experimental Design

In this study, Taguchi method was used for experimental design and analysis. This method is useful for both analyzing interactions among variables and in terms of costs- effectiveness [25-26]. In experimental studies, values obtained from the objective function are converted into signal/noise (S/N) ratios in order to determine the performances of levels belonging to control factors against uncontrollable factors [27]. In determining the S/N ratio, "smaller the better, bigger the better, nominal is best" objective functions are used. ANOVA (Analysis of Variance) is used to determine whether independent variables are statistically significant or not. In this way, optimization validity is determined by conducting confirmation tests after determining the optimum conditions with the help of S/N ratios and ANOVA [28]. In this study, optimization for cutting parameters to achieve minimum diameter deviation in drilling HSLA materials was carried out. Cutting parameters were determined by conducting three preliminary experiments for same parameters. Besides, cutting speed (m/min) and feed rate (mm/rev) were determined as the independent variables and three different levels were fixed for each independent variable. As the experimental design Taguchi's L_9 (3^2) orthogonal experimental scheme was used. The independent variables and levels of these variables are given in Table 4.

Table 4. Independent variables and levels

Variances	Control factors	Symbol	Level 1	Level 2	Level 3
A	Cutting speed (m/min)	*V*	10	26	42
B	Feed rate (mm/rev)	*f*	0.05	0.075	0.1

In determining the optimal levels of independent variables, it is desired that the diameter deviation is minimized. Therefore, the objective function with "smaller the better" for the performance characteristic was used to determine the S/N ratios in Equation 1.

$$S/N_{SB} = -10 \log\left(\frac{1}{n}\sum_{i=1}^{n} Yi^2\right) \qquad (1)$$

For the experimental results, the level of effects of the independent variables on diameter deviation were determined by using of ANOVA at a 95% confidence interval (α=0.05).

3. EXPERIMENTAL RESULTS

Table 5 shows the diameter deviation (Dd) measured as a result of the drilling operation performed with HSLA material based on the L_9 orthogonal experimental design. It also shows the calculated S/N values based on "smaller the better" objective function of Taguchi.

Table 5. According to Taguchi L_9 orthogonal array experimental results and S/N ratios

Order	A	B	Uncoated HSS drill		TiAlN coated HSS drill	
	1	2	D_d (mm)	S/N (dB)	D_d (mm)	S/N (dB)
1	10	0.05	0.013	37.721	0.01	40.000
2	10	0.075	0.016	35.917	0.014	37.077
3	10	0.1	0.02	33.979	0.018	34.894
4	26	0.05	0.016	35.917	0.015	36.478
5	26	0.075	0.019	34.424	0.017	35.391
6	26	0.1	0.023	32.765	0.021	33.555
7	42	0.05	0.019	34.424	0.016	35.917
8	42	0.075	0.02	33.979	0.018	34.894
9	42	0.1	0.025	32.041	0.023	32.765

The diameter deviation (Dd) and S/N plots measured as a result of the drilling operations carried out with TiAlN coated and uncoated drills for each cutting speed based on feed rate are given in Figure 2.

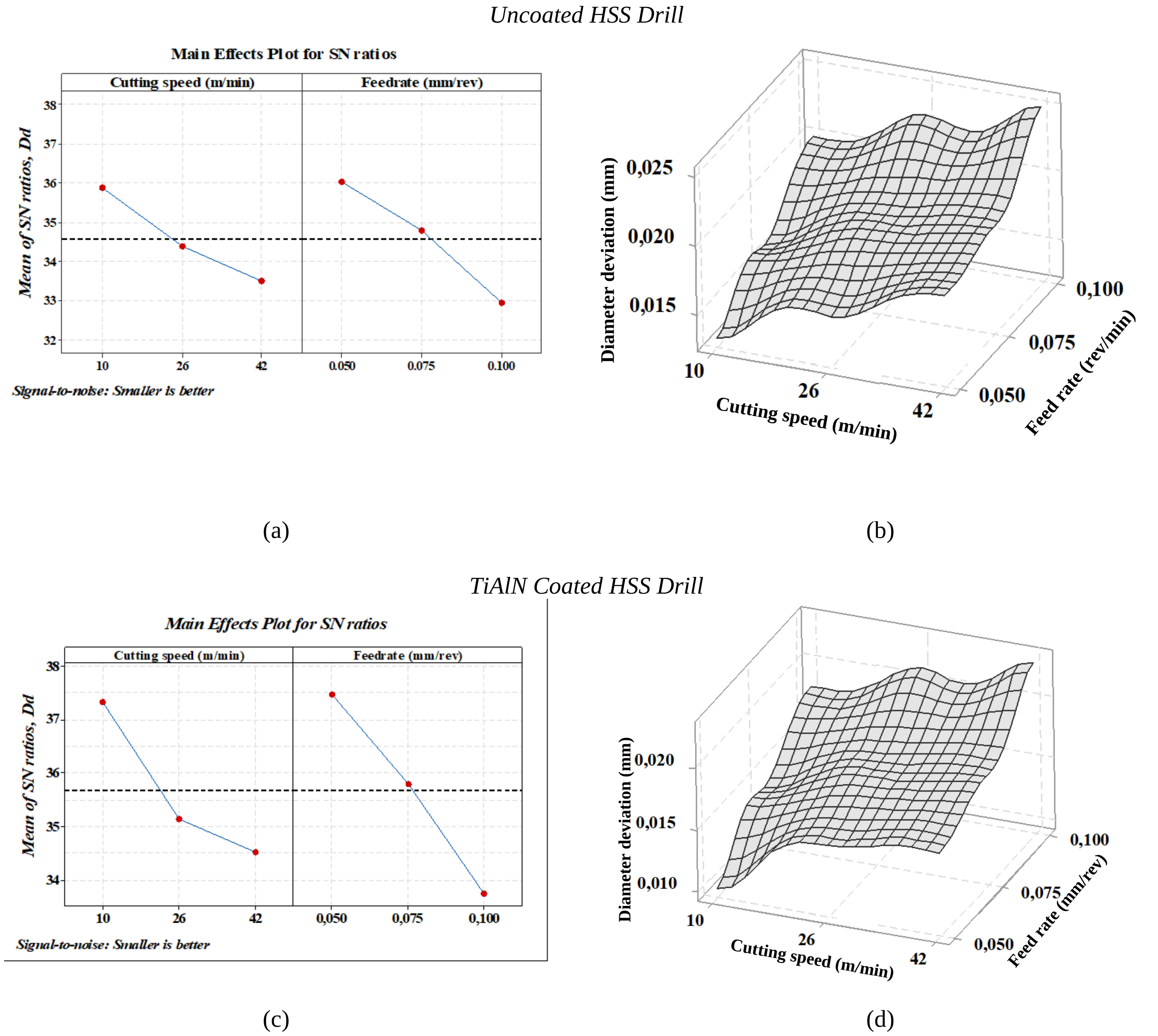


Fig. 2. S/N ratios and diameter deviations for the drilled holes, a) S/N ratios for uncoated HSS drills, b) Effect of feed rate and cutting speed on diameter deviation for uncoated HSS drills, c) S/N ratios for TiAlN coated HSS drills, d) Effect of feed rate and cutting speed on diameter deviation for TiAlN coated HSS drills.

Considering Figure 2. a-c, the optimum parameters for diameter deviation in the drilling processes with uncoated and TiA1N coated HSS drills were found as A_1 (10 m/min) and B_1 (0.05 mm/rev). In Figure 2. b-d, it was observed that diameter deviation increased along with the increases in feed rate. This is caused by the increase in the chip cross-section removed per unit time [24] and the loads occurring on the cutting tools due to the pressure [29-30]. Additionally, it was seen that diameter deviation also increased in line with the increased cutting speed (Figure 2. b-d). This increase in diameter deviation is considered to have been resulted from the effects of high cutting speeds on vibrations that occur during cutting [17]. While friction increased between cutting tool and work piece with increasing cutting speed, idle machining time decreased [31]. When cutting tools are analyzed, it was observed that diameter deviation measured for TiA1N coated tools was lower than that those for uncoated tools. Low friction of the coated tools made the cutting process relatively easier and in parallel with this, forces experienced during cutting also decreased. This situation leads to lower values of diameter deviation with TiA1N coated tools as it was also reported in literature [17].

3.1. Analysis of Variance (ANOVA) Results

Table 6 shows the ANOVA results calculated to determine the effects of the independent variables on diameter deviation for uncoated and TiA1N coated HSS drills. $P<0.05$ was accepted as the level of statistical significance. Accordingly, based on Table 6, the most important factor on diameter deviation was feed rate in both uncoated and TiA1N coated HSS drills by 61.490 % and 60.147 %, respectively. The effect of cutting speed, on the other hand, for uncoated and TiAlN coated HSS drills was found as 37.104 % and as 37.325 %, respectively. The abbreviations in Table 1 are Degree of Freedom (DF), Sum of Squares (SS), Means of squares (MS), and Percentage contribution (PC) respectively.

Table 6. ANOVA results for diameter deviation

Source	DF	SS	MS	F	P	PC (%)
Uncoated HSS Drills						
Cutting speed (m/min)	2	8.764	4.382	26.40	0.005	37.104
Feed rate (mm/rev)	2	14.524	7.262	43.76	0.002	61.490
Error	4	0.663	0.166			1.406
Total	8	23.952				100
TiAlN coated HSS drills						
Cutting speed(m/min)	2	12.972	6.485	14.76	0.014	37.325
Feed rate (mm/rev)	2	20.902	10.450	23.78	0.006	60.147
Error	4	1.758	0.439			2.528
Total	8	35.631				100

Three further experiments were conducted for the optimum levels determined for each type of cutting tools in order to test the accuracy of the experiment results. The results of confirmation experiments were reported by taking the arithmetic mean of the results obtained from experiments. Accordingly, Table 7 shows that the optimization process was successful considering the results of confirmation experiments.

Table 7. Optimum and verification results for diameter deviation

Taguchi Optimization	Uncoated HSS drills		TiAlN coated HSS drills	
	Predicted	Verification	Predicted	Verification
Levels	A1B1	A1B1	A1B1	A1B1
Cutting conditions	10 / 0.05	10 / 0.05	10 / 0.05	10 / 0.05
Diameter deviation (mm)	0.013	0.016	0.010	0.012

4. CONCLUSIONS

In this study, a high strength low alloy (HSLA) material was drilled using uncoated and TiA1N coated HSS drills, and the effects of cutting parameters on diameter deviation were investigated. The main outcomes from the study can be summarized as follows;

- Diameter deviation was lower with TiAlN coated drills than that with uncoated drills,
- Diameter deviation increased in line with increased cutting speeds in both TiAlN coated and uncoated tools,
- Feed rate had a greater effect on diameter deviation with both types of cutting tools,
- The optimum level of cutting speed and feed rate were determined as A_1 (10 m/min) and B_1 (0.05 rev/min), respectively in both cutting tools,
- It was determined that the optimization was successful in the light of the data obtained as a result of confirmation experiments.

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Research Article | Submit Manuscript

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An Efficient Controller for Standalone Hybrid - PV Powered System

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ABSTRACT This paper presents a new technique for enhancing the dynamic performance of a conventional proportional integral (PI) controller to achieve faster and ripple-free Maximum Power Tracking (MPPT) for standalone hybrid photovoltaic (PV) systems using an augmented fuzzy logic controller (FLC) with PI controller. The dynamic performance of the augmented PI-Fuzzy Control Scheme is compared with conventional PI controller. The additional requirement of battery bank State of the Charge (SOC) regulation is added to ensure battery charging based on PV power condition using the common DC bus voltage. The dynamic performance is examined using Matlab-Simulink software environment and simulation under different operating conditions such as uniform, irregular insolation/irradiation level, disconnected battery and electric load changes. AC side loads are connected to the standalone hybrid PV system using six pulses inverter. Dynamic simulation results validated the fast response and reduced transients and ripple content using the proposed Fuzzy-PI controller while achieving MPPT for uniform and varying insolation/irradiation levels.

Keywords: Maximum power point tracking (MPPT), Modeling of standalone PV system, Fuzzy -PI augmented controller.
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1. INTRODUCTION

Electrical power generated from PV arrays and farms is emerging as a viable, clean and economical alternative energy for residential, commercial industrial as well as electric utility back up and additional energy sources [1]. The power of PV arrays is varied due to weather changes, such as variations in insolation/irradiation levels and operating temperatures [2]. Maximum Power Point Tracking (MPPT) controller is customarily used to achieve the maximum Power/Energy Utilization of the PV system, where MPPT search algorithm or dynamic tracking is embedded in the regulation system. Nonlinear characteristic of the PV Volt-Ampere relationship is one of the major challenges in dealing with PV source-nonlinearity under PV array-insolation/irradiation changes [3-4].

Many techniques are utilized to achieve MPPT such as hill climbing, incremental conductance methods and perturb and observe (P&O). P&O is considered the most commonly used method in industrial PV applications yet it has drawbacks when the process reaches MPP, the controller forces the operating point to go back and oscillate around MPP. In this study, the PI controller is used to achieve MPPT due to changing the weather conditions such as irradiance level. In partly cloudy weather condition, the performance of PV output reduces. Partial shading may also be caused by adjacent buildings and shadow of panel, since the irradiation level is intermittent. Therefore, it is required to parallel PV with an energy storage source to compensate the load demand. It is also necessary to store the unused solar power. Li-Ion rechargeable batteries provide highly efficient, reliable, and convenient performance in both high energy and low energy applications [6]. They can be used in linear generators, backup and hybrid vehicle systems.

The control algorithm, on the other hand, plays a vital role in reliable and continuous operation of the hybrid system. The performance of the controller is studied under crucial cases, such as battery disconnection or defected battery. In such cases, the output powers oscillate and loose the tracking point. In PV- hybrid system, backup storage batteries play a vital role in storing energy, and delivering the load during the night, or compensate the required power to the load under partial shadow [6].

The DC output voltage from PV arrays is used to charge the battery using DC-DC converter. Battery disconnects/defective state is considered one of the major problems of the hybrid PV- stand-alone systems. When the battery is disconnected, the performance of the controller is affected as the PV array output is significantly reduced. The proposed augmented FLC-PI controller is utilizing a fuzzy logic controller (FLC) stage, added to the PI controller, to achieve the MPPT charging state and environmental conditions. Also, PI controller is used to control the charging state of the battery (SOC) [7]. The dynamic performance of the proposed FLC-PI controller is studied under different conditions, such as changing irradiance levels, partial shadow and battery disconnection.

2. SYSTEM CONFIGURATION

The block diagram of the proposed system is shown in Figure 1. The system consists of an energy conversion unit (solar PV system), a backup storage nickel metal hydride (Ni-MH battery), main control unit (MPPT controller), DC-DC converter, and an inverter converting DC power to AC power. The major function of the controller is to achieve MPPT and provides the PWM (Pulse Wide Modulation) signal for the DC-DC converter to charge the battery based on the SOC. Parameters of the PV array, controller and battery are provided in the Appendix1.

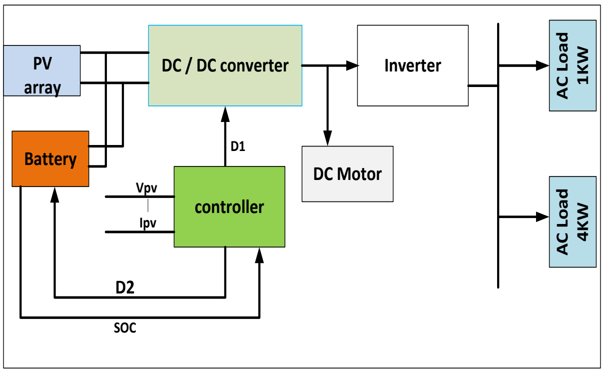


Fig. 1. Sample study system configuration

2.1. Fuzzy Logic Control (FLC)

The basic structure of fuzzy logic controller, which includes scaling factors, fuzzification, and inference engine, rule base and membership function, defuzzification, is shown in Figure 2. Fuzzy controllers are very simple in concept [9]. They consist of an input stage, a processing stage, and an output stage. The input stage maps sensors or other inputs, such as switches, thumb-wheels, etc. to the appropriate membership functions and truth-values. The processing stage invokes each appropriate rule and generates a result for each, then combines the results of the rules. Finally, the output stage converts the combined result back into a specific control output value. The most common shape of membership functions is triangular, although trapezoids, Gaussian, and bell curves are also used. Nonetheless, the shape is generally less important than the number of curves and their placement. Fuzzy-controller has many benefits over PID [9], for example, they can cover a much wider range of operating conditions than PID, and can operate with noise and disturbances. The input for the fuzzy controller is chosen to be powered from the PV array (*P*) where *P* is an error (e) signal. *Δe* is defined as the change of ΔP. Under varying irradiation and temperature, FLC achieves better performance than the PI control method [10]. Nevertheless, the choice of the rule base table of FLC affects greatly the effectiveness [15].

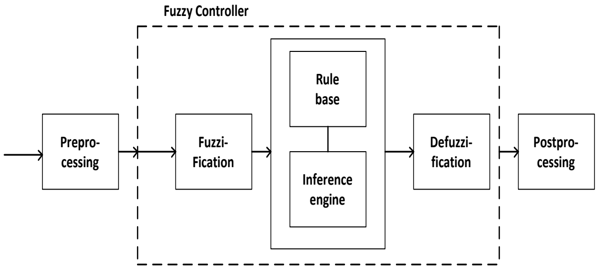


Fig. 2. Fuzzy controller structure

The proposed fuzzy-controller was designed according to Table 1, the two inputs for (FLC) are error (e), and change in error (*Δe*). Inputs for the proposed fuzzy controller are power *P* and change in power ΔP. A triangular membership function was selected to describe the input (e), and change in error, (*Δe*)

Table 1. FLC assignment matrix with rules*

e \ Δe	NB	NS	Z	PS	PB
NB	PB	PB	PS	PS	Z
NS	PB	PS	PS	Z	PS
Z	PB	PS	Z	NS	NB
PS	NS	Z	NS	NS	NB
PB	Z	NS	NB	NS	NB

*Membership States: Z: zero, S: small, B: Big, P: positive, N: negative, NB: negative big, PB: positive big, etc.

According to Table 1, both error and change in error are described through the rules. For example, if error is PB (positive big), a change in error is PS (positive small), and then the control signal is PM (positive medium). The error (*e*) and change of error (*Δe*) are given by Equations (1) and (2), respectively.

$$e = P(k) \quad (1)$$

$$\Delta e(k) = e(k) - e(k-1) \quad (2)$$

2.2 Modeling of PV Array

Accurate mathematical model is necessary to represent the electric characteristics of PV module [2, 5]. The conventional equivalent circuit of a solar cell is expressed by one or two diodes, whereas representing by a photo-current source, parallel diode, shunt resistance (R_{sh}), and series resistance (R_s) as is seen in Figure 3. The current source (I_{pv}) models the sunlight energy conversion, the shunt resistance represents the consequence of leaks, the series resistance represents the various resistances of connections, and the diodes model the *p-n* junctions.

PV cells are usually interconnected in series-parallel configuration, to form PV modules and arrays. PV array is modeled [1] by Equation 3.

$$\mathrm{I_m} = I_{ph} - \mathrm{I_d}\left[\exp\left(\frac{\mathrm{q}(V_{ph}+I_m\mathrm{R_s})}{n\mathrm{K_T}}\right) - 1\right] - \frac{V_{ph}+I_m\mathrm{R_s}}{\mathrm{R_{sh}}}) \qquad (3)$$

Where *q* is the charge on electron, *n* is the number of cells in series, *k* is the Boltzmann constant and *T* is the absolute temperature (Kelvin), I_{ph} is the photo-electric current, and I_m is the current generated by PV array.

$$\mathrm{I_{ph}} = \mathrm{I_{sco}}\left(\frac{G}{\mathrm{G_0}}\right)\left(1+\alpha(T-\mathrm{T_0})\right)\left(\frac{\mathrm{R_s}+\mathrm{R_{sh}}}{\mathrm{R_{sh}}}\right) \qquad (4)$$

Where I_{sco} is the short circuit current of the module at standard irradiation G_o (1000W/m²) and standard temperature T_0 (25 ^{o}C), and α is the module's temperature coefficient. The PV array is modeled using the equations mentioned above. The PV module specifications at standard test conditions are given in Appendix 1.

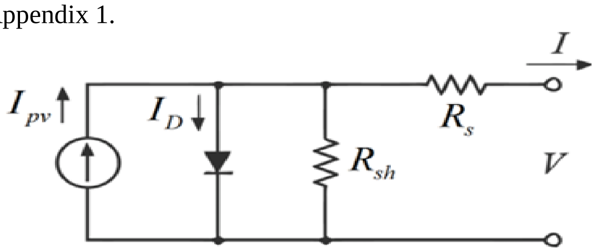


Fig. 3. Equivalent circuit of PV

2.3. Proposed Controller

The configuration of the proposed controller is based on using a cascading controller. The primary controller is a fuzzy logic controller (FLC), and the second controller is PI. The configuration of FLC is used according to Figure 2. The trapezoidal membership function is used to describe both input and output. The inputs of the proposed controller are (*P*), where *P* is the output power from PV, and then the output from the FLC controller is considered as a reference DC value of the PI controller. When the solar power is higher than the output power, since there is no need to discharge the battery, the duty cycle (D_2) is controlled by PI control for regulation. In this case, PV energy flows to the output as well as to the battery. Therefore, extra power generated by PV system can be stored, and then can be transferred to the output when necessary. The PI controller is used to control the charging state of the battery (SOC), where power from PV array is used to charge the battery through a buck converter, which acts as a maximum power point tracker.

The FLC-PI is used to achieve MPPT of PV- hybrid system under crucial conditions, such as large changes in the irradiance level, partial shadow, battery disconnection, and short circuit in AC side. A comparison between the traditional PI controllers was implemented in this study.

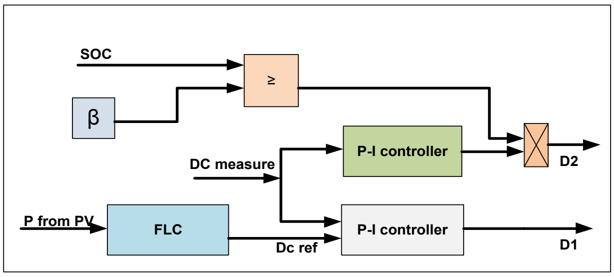


Fig. 4. Proposed augmented FLC-PI controller

3. SIMULATION RESULTS

To ensure the effectiveness and validation of the augmented FLC-PI controller, its comparison with conventional MPP-PI controller is presented. Tracking MPP under varying load insolation/irradiation and battery state of the charge is achieved. The proposed controller and the convention PI were tested, and then their performance was compared. The step response of the proposed controller is examined under two different set points. The set points were considered the power output of the system at the solar irradiances of 950 W/m^2 and 450 W/m^2. Initial set point was 950 W/m^2 where the obtained power was determined as 940 W, for the time period of 900 msec. the irradiance level falls down to be 450 W/m^2. Figure 5 shows a comparison between the PI, and proposed controller under changing in radiation level. Both algorithms are successful to reach the operating point quickly, but it's noticed that the over shot in case of using FLC-PI is less than that for PI controller.

The response of both controllers are analyzed under partial shadow [14] according to irradiance profile Figure 6(a) , the PV array divided into two groups, first group subject to irradiance profile level 1, and the other subjected to irradiance profile level 2. Figure 6(b) shows the rapidness of the proposed FLC- PI controller to reach the operating point and was achieved better performance tracking than using the conventional PI. Furthermore the responses of both controllers are examined during disconnection of the battery. PV array is kept under partial shadow, to evaluate the system performance, and prove the effectiveness of the proposed controller. There are many applications using the hybrid PV system (PV & battery) [8], such as cathodic protection system. When the battery was defected or disconnected, the system cannot accomplish the requirement. Simulation results proved this fact. Figure (7) shows the output power that obtained from both controllers. The augmented FLC-PI is successful to reach the operating point quickly, and achieve MPPT, and keeps the system working properly as compared with the PI controller.

Another point should be taken into consideration is to study the effect of short circuit (SC), when it's occurred in the AC side for a certain time. Figure 8 show the performance of the FLC-PI under short circuit (SC). It's noticed that the large value of reactive power in case of using PI as compared with augmented FLC- PI. The results also revealed that the proposed controller able to achieve better performance under this crucial condition and tracking of MPP. Battery bank was installed for better utilization of PV array off grid system. During sunlight the output power from PV is used to charge the battery bank and feeding the inverter. At night there is no output power from the PV array, then the battery bank is used to feed the load, also under partial shadow the demand out power from PV array was reduced. Hence; the battery bank compensates the required power to the inverter to feed the load. Figure 9 (b), (d), and (e) show the battery power with respect to time. It observed that PV power changes with respect to the solar irradiance. The compensation from a battery under partial-shadow and night is presented when the demand output power is higher than PV power. In addition the AC load was changed from 1kW to be 4 kW. Figure 9 (f) shows the performance of the controller.

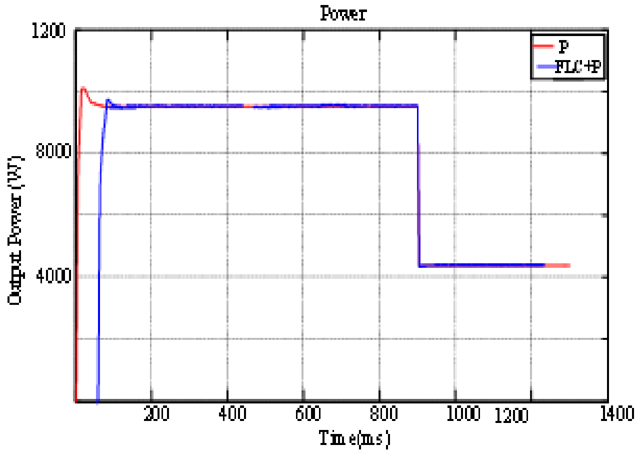


Fig. 5. Output power under insolation/the irradiance levels from 9560 to 4560 W/m^2

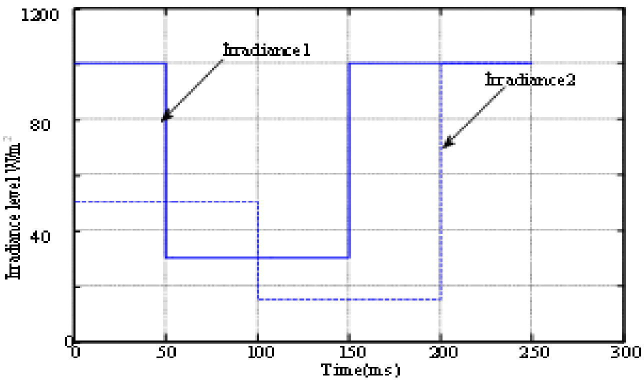


Fig. 6. (a) Irradiation level

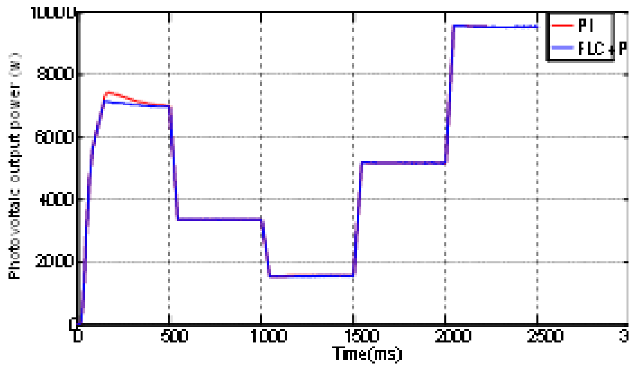


Fig. 6. (b) Output power under partial shadow

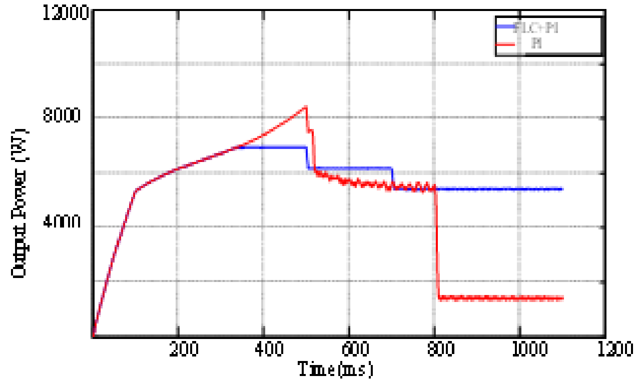


Fig.7. Output power under partial shadow when the battery bank disconnected

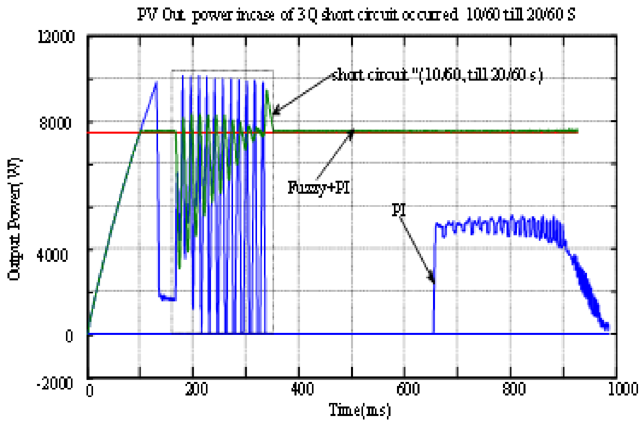


Fig. 8. (a) Output power under SC occurred from AC side for a certain time in case of battery disconnected

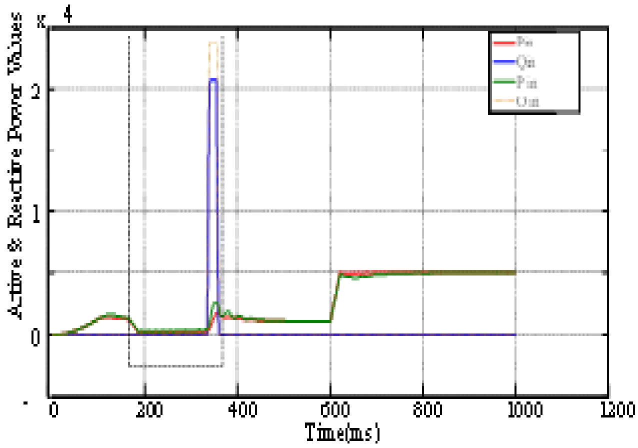


Fig. 8. (b) P&Q inverter AC power during SC

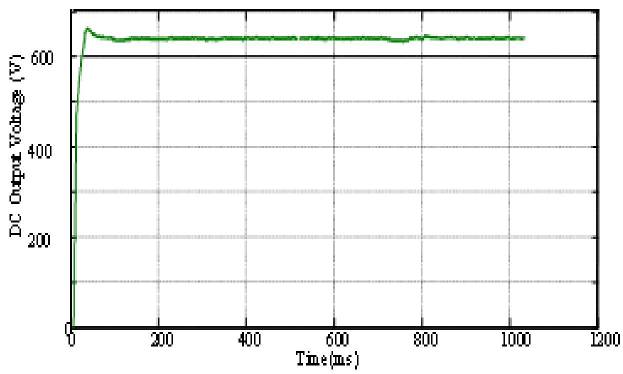


Fig. 9. (a) DC bus voltage at night

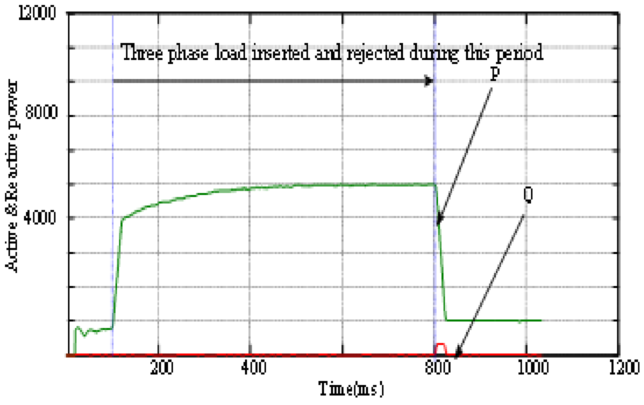


Fig. 9. (b) Load feeding from battery at night

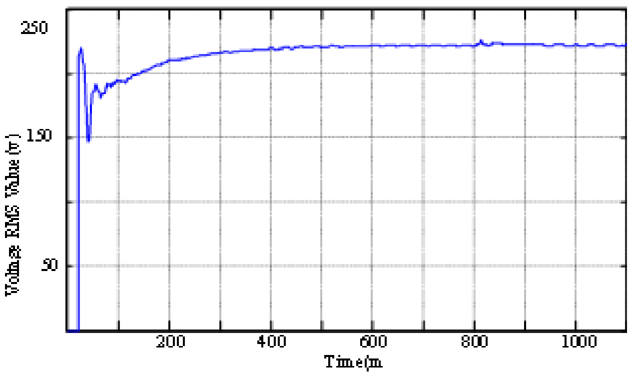


Fig. 9. (c) Inverter V_{rms} value for one phase

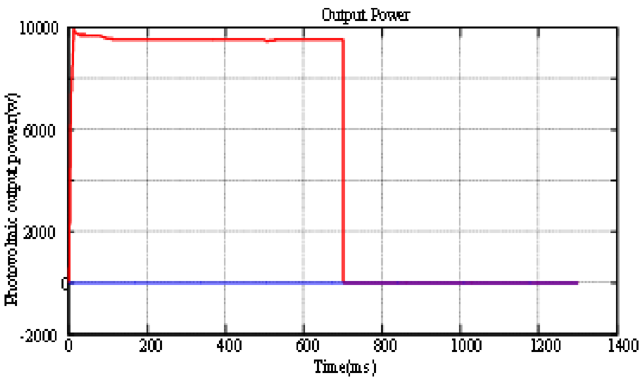


Fig. 9. (d) Output power under sunlight existing and night conditions

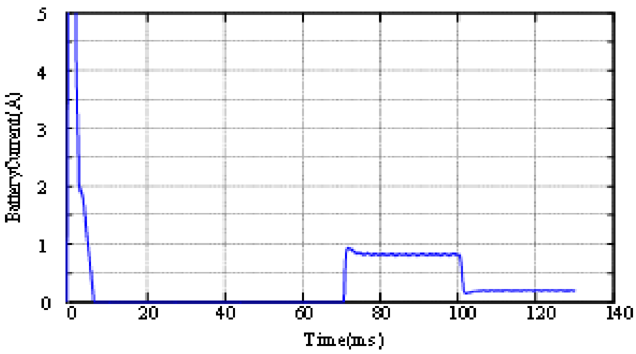


Fig. 9. (e) Battery current compensation levels

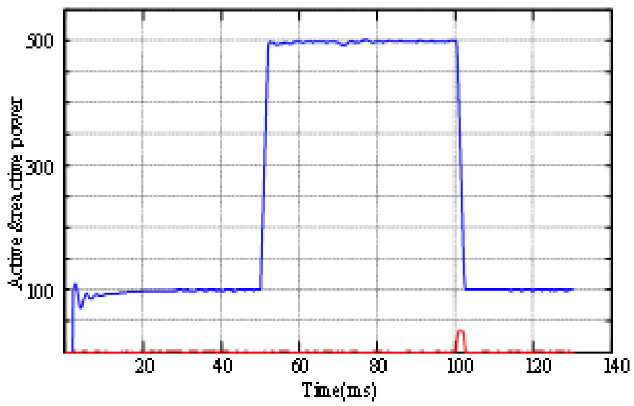


Fig. 9. (f) Active and reactive power during acceptance test

4. CONCLUSION

The paper presented an augmented FLC-PI MPPT control scheme for standalone PV-Battery hybrid system. The FLC-PI augmented controller is compared with classical PI-MPPT controller and evaluated for effectiveness under varying load, insolation/irradiation and battery state of the charge. PV array power is used to charge the battery through a double functional regulation of the buck DC/DC converter which also used for maximum power point tracking. The new augmented FLC-PI is compared with conventional MPPT PI controller and validated under different operating conditions, and digital simulation results validated its dynamic effectiveness in tracking and battery charging with less ripple, inrush and transient voltage conditions. The proposed structure of the FLC-PI is now being extended to multi array PV farms with DC and AC type loads and interface to smart grid with restrictions on total harmonic distortion and requirement for improved power quality using modified PWM switching strategies.

APPENDICES

Appendix i: PV array parameters

Parameters	Values
Rated Power	10 kW
Open circuit voltage (V_{oc})	406 V_{DC}
Number of parallel cells	44
Maksimum power point voltage (V_{mpp})	336 V_{DC}
DC bus value	640Vd_{DC}
Series resistance (R_s)	0.055 Ω
Shunt resistance (R_{sh})	550 Ω

Appendix ii: Battery parameters with charge control

Parameters	Values
Nominal Voltage	320 V
Rated Capacity	6.5 Ah
Maximum Capacity	7 Ah
Fully Charged Voltage	353 V
Parameters for charging PI(Discrete)	**Values**
Proportional value (Kp)	2
Integral term value (K(i))	120
β minimum charge value	0.8

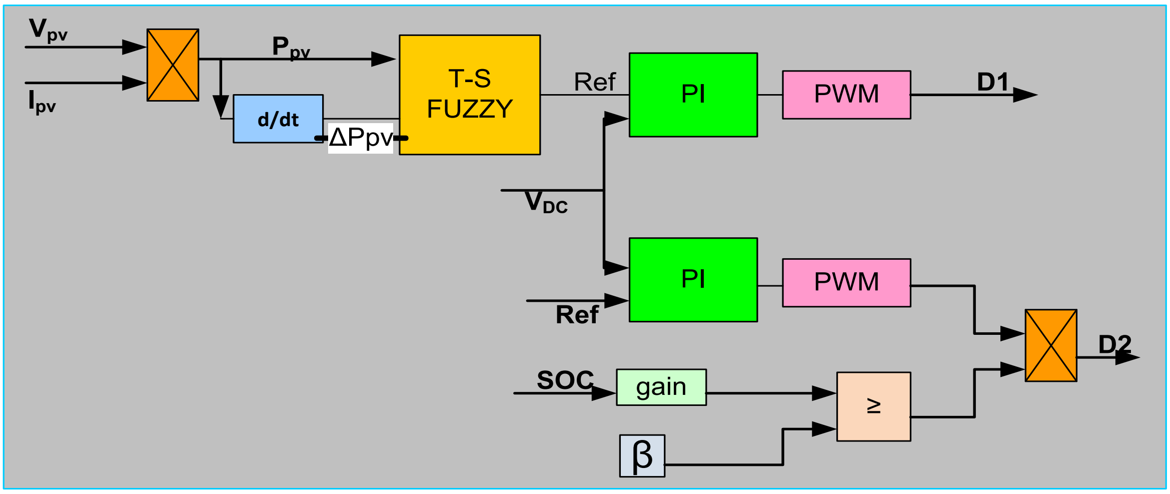
Appendix iii: Loads parameters

Parametres	Values
AC Load_1(Three phase RLC)	1kW, 50Hz, 400V_{AC}
AC Load_2(Three phase RLC)	4kW, 50Hz,400V_{AC}
DC load motor	5 HP
Field voltage	300V_{DC}
R_a	11.2 Ω
L_a	0.1215 H
R_f	281.3Ω
L_f	156 H
Load torque (constant)	1N.m
Motor Speed	1750 r.p.m

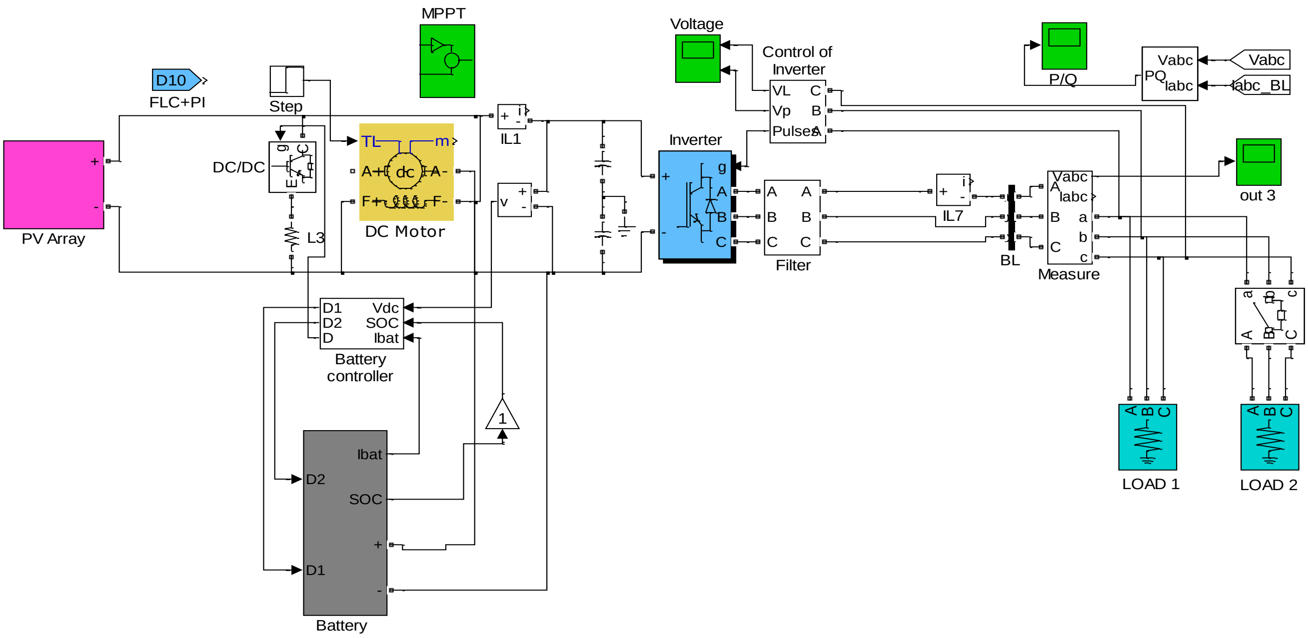
Appendix iv: Controller's & inverter parameters

Parameters for PI (Discrete)	**Value**
Proportional value (*Kp*)	60
Integral term value (*Ki*)	500
Parameters for FLC	**Value**
Error gain (*e(k))*	0.16
Change of error (Δ*e*)	0.1
Control signal (D(u))	320
Universal bridge (inverter)	**Value**
Number of bridge arms	3
Power electronic devices	IGBT/Diodes
Snubber resistance (R_s)	5000

Appendix v: Proposed controller



Appendix vi: Matlab/Simulink model of general system



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