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A Study on PKL Electrochemical Cell for Three Different Conditions

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Abstract It has been conducted this research work to measure the short-circuit current (I_{sc}) and capacity ($C = \text{AH}$) for different conditions of the PKL (Pathor Kuchi Leaf). The copper and zinc plates have been embedded between the two ends of the PKL for three different conditions like fresh leaves, dry leaves and living leaves to make PKL electrochemical cells. The plates were kept tightly binding by plastic clips. A sophisticated multimeter was used to measure the short-circuit current (I_{sc}). The short-circuit current was recorded after 12 h interval. It was seen that the obtained maximum current was 0.7 A for living PKL tree and the minimum current was recorded for dry PKL about 0.10 A for dry PKL. The variation between maximum and minimum short-circuit current difference is for dry PKL is 0.14 A, for

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fresh PKL is 0.10 A and for living PKL tree is 0.00 A. The maximum capacity was 67.2 AH for living PKL tree and the minimum capacity was 2.16 AH for dry PKL. This type of works has been conducted by us for the first time in Bangladesh. It will help the poor for practical power applications with solar photovoltaic systems. There are some differences from the SPV (Solar Photovoltaic System). The SPV system did not work at night and rainy season. But these PKL power woks equally both day and night time. Furthermore, the PKL power technology is new and innovated technology in Bangladesh whereas the SPV device was innovated by a Russian scientist. For better performance of the PKL electrochemical cell, Some Performance and operation characteristics of the PKL electrochemical cell like input–output curves, efficiency curves, heat rate and incremental curves have been conducted. Finally, the performance of the PKL electrochemical extract cell has been studied by magnetic stirrer with hot plate. It is found that the performance of the PKL cell increases after making oscillation for PKL filtered extract by magnetic stirrer with hot plate.

Keywords Capacity · PKL electrochemical cell · Living leaves · Fresh leaves · Dry leaves · Short-circuit current · Operation characteristics

1 Introduction

Energy is the driving force of human civilization [1, 2]. To keep in mind it has been conducted research work on PKL power system [3, 4]. It is a very new and innovative work around the globe. It has been patented by the first author. Now a day some developing countries are facing problems with electricity. They are using solar electricity at the off-grid areas [5, 6]. Now it can be started PKL power for lighting purposes. The traditional source of electricity will be finished within 2100 across the globe [7, 8]. Then we have to depend on renewable energy sources. PKL power is the application of biomass energy. Our research work will be the guideline of practical applications of new electricity in the near future [9]. The definition of capacity of a PKL electrochemical cell is how much current you will get for how long time [10]. Most of the results have been tabulated and graphically discussed. The traditional sources of energy are diminishing rapidly day by day rapidly [11, 12]. That is why scientists are trying to face the future energy crisis through renewable energy [13, 14]. Biomass energy sources are one of the most important sources of renewable energy sources across the world [15]. In this research paper, biomass energy source has been used in a different and innovative way. For better working of the PKL electrochemical cell, some performance and operation characteristics of the PKL electrochemical cell like input–output curves, efficiency curves, heat rate and incremental curves have been conducted. PKL has been used in three different ways for electricity extraction. Finally, comparative studies have been conducted among three different PKL extracts based electrochemical cells.

2 Methodology

2.1 Capacity and Short-Circuit Current of and PKL Electrochemical Cell

The definition of capacity (C) of a PKL electrochemical cell is how much current you will get for how long time. The short-circuit current (I_{sc}) means—the current without load. Figure 1 shows the method of the experimental set up for measurement of short-circuit current (I_{sc}) and capacity (C = AH) of a PKL electrochemical cell for living PKL tree, dry PKL, and fresh PKL. It has been collected living PKL tree first. Then leaf has been picked from the living PKL tree. This leaf was treated as a fresh leaf. After collection of the leaf, it has been dried and treated as a dry leaf. The short-circuit current has been collected from living, fresh, and drying leaves with a calibrated multimeter. The tabulated data is shown in Table 1. The data was collected every 12 h interval.

(a) power from living PKL tree (b) power from dry PKL (c) power from fresh PKL

Fig. 1 Experimental set up for measurement of short-circuit current (I_{sc}) and capacity (C = AH) of a PKL electrochemical cell for living PKL tree, dry PKL and fresh PKL

Table 1 Data for collection of short-circuit current (I_{sc}) and capacity (C = AH)

Time duration (h)	Short-circuit current, I_{sc} (A) for dry PKL	Short-circuit current, I_{sc} (A) for fresh PKL	Short-circuit current, I_{sc} (A) for one living PKL	Capacity (C = AH) for dry PKL	Capacity (C = AH) for fresh PKL	Capacity ($C(a)$ = AH) for living PKL
12	0.18	0.20	0.7	2.16	2.4	8.4
24	0.24	0.30	0.7	5.76	7.2	16.8
48	0.20	0.25	0.7	9.6	12	33.6
72	0.15	0.23	0.7	10.8	16.56	50.4
96	0.10	0.20	0.7	9.6	19.2	67.2

2.2 Energy Cost of the PKL Electrical System

It consists the costs namely: (1) Cost of operating labour and materials, (2) Cost of supplies such as PKL extract treatment chemicals, PKL extract filtration cost, PKL extract preparation cost, PKL cultivation cost, Insulator box preparation cost, Connecting wire cost, Different helping Tools costs, Electrodes purchasing costs, and Maintenance costs. The total costs depend on the size and volume of the PKL power plant.

2.3 Performance and Operation Characteristics of the PKL Electrochemical Cell

PKL extract which acts as electrolyte and electrodes of PKL electrical system should work efficiently. Some curves are plotted to observe their performance. The various curves used are as follows:

1. **Input–output curves**: Performance of a PKL electrical system is precisely described by the input–output curve which is a graphical representation between the net energy output (L) and input (I).
2. **Efficiency curve**: The energy efficiency of the PKL cell = E_D/E_C, where, E_D = Total energy during charging, E_C = Total energy during discharging. Now, if V_c = Charging voltage (V), I_c = Charging current (A), T_c = Charging time (h). Therefore, $E_C = V_c\, I_c\, T_c$ and if $E_D = V_D\, I_D\, T_D$, where, V_D = discharging voltage (V), I_D = discharging current (A), T_D = discharging time (h). Therefore, energy efficiency = $E_D/E_C = (V_D\, I_D\, T_D)/(V_c\, I_c\, T_c) = (V_D/V_c)\,(I_D\, T_D)/(I_c\, T_c)$ = (Voltaic efficiency)(Columbic efficiency), where, Voltaic efficiency = (V_D/V_c) and Columbic efficiency = $(I_D\, T_D)/(I_c\, T_c)$ (Table 2).
3. **Heat rate curve**: The ratio of input to output is known as heat rate (HR). Therefore, HR = I/L. where L = energy output and I = energy input.
4. **Incremental rate**: It is defined, IR = $\mathrm{d}I/\mathrm{d}L$, where, IR = Incremental rate, $\mathrm{d}I$ = change in input energy and $\mathrm{d}L$ = change in output energy.

2.4 Effect of Oscillation for the Filtrated Fresh PKL Extracts Use in PKL Electrochemical Cell

Figure 2a shows the open-circuit voltage before use stirrer. Figure 2b shows a magnetic stirrer with hot plate for use in PKL electrochemical cell to generate PKL electricity. The PKL extract after filtration was set up on the hot plate of the magnetic stirrer. It had been set up there on working condition around half an hour. It is mentioned that the amount of PKL extract was 250 cc. Then two Zn and Cu

Table 2 Table for energy efficiency of a PKL electrochemical cell

Time duration (h)	Voltage efficiency (%)	Columbic efficiency (%)	Energy efficiency (%)	Energy input, I (W)	Heat rate (HR) = I/L	Income rate (IR) = dI/dL	Energy output, L(W)
0	88	90	79.2	1.05	1.27	0	0.83
1	86	89	76.54	1.05	1.31	1	0.80
2	85.5	89	76.1	1.04	1.32	0	0.79
3	85	88	74.8	1.04	1.33	0	0.78
4	84	87	73.08	1.04	1.37	0	0.76
6	84	85.5	71.82	1.04	1.39	0	0.75
7	83.5	83.9	70.06	1.04	1.42	0	0.73
8	83	83.8	69.55	1.04	1.44	0	0.72
9	82	83	68.06	1.03	1.47	0.5	0.70
10	80	82	67.20	1.03	1.49	0	0.69

(a) Open circuit voltage before use of stirrer (b) Magnetic stirrer with hot plate (c) Open circuit voltage after use of stirrer

Fig. 2 An experimental set up for the use of magnetic stirrer with hot plate

electrodes were immersed partially in that fresh PKL extract to harness open-circuit voltage. The data have been tabulated (Table 2) and graphically represented. Figure 2c shows the open-circuit voltage before use of stirrer (Table 3).

3 Results and Discussion

Figure 3a shows the Variation of Short-circuit Current, I_{sc} (A) for (a) dry PKL (b) fresh PKL and (c) living PKL with the variation of time durations (h). It is also shown that the maximum current was 0.24 A and the minimum current was 0.10 A. It has been found the short-circuit current was increased up to 24 h that then it was decreased almost linearly up to 96 h. The difference between maximum and minimum short-circuit current is 0.14 A.

Figure 3b shows the Variation of Short-circuit Current, I_{sc} (A) for fresh PKL with the variation of time durations (h). It is also shown that the maximum current was 0.30 A and the minimum current was 0.20 A. It has been found the short-circuit

Table 3 Table for data collection of open-circuit voltage before and after using magnetic stirrer with hot plate

Time duration (h)	Open-circuit voltage, V_{oc} (V) before use magnetic stirrer	Open-circuit voltage, V_{oc} (V) after use magnetic stirrer
0	0.98	1.03
1	0.98	1.03
2	0.98	1.03
3	0.98	1.03
4	0.98	1.03
5	0.98	1.03
6	0.98	1.03
7	0.97	1.03
8	0.97	1.03
9	0.97	1.03
10	0.97	1.03

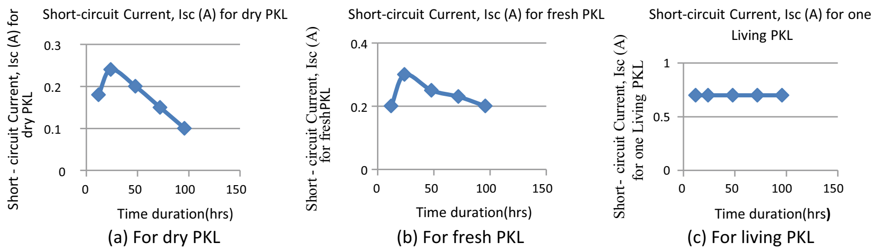


Fig. 3 Variation of short-circuit current, I_{sc} (A) for dry PKL, fresh PKL and living PKL with the variation of time durations (h)

current was increased up to 24 h that then it was decreased almost linearly up to 96 h. The difference between maximum and minimum short-circuit current is 0.10 A.

Figure 3c shows the Variation of Short-circuit Current, I_{sc} (A) for living PKL with the variation of time durations (h). It is also shown that the maximum current was 0.70 A and the minimum current was 0.70 A. It has been found the short-circuit current was almost constant up to 96 h. The difference between maximum and minimum short-circuit current is 0.00 A.

Figure 4a shows the variation of capacity ($C =$ AH) for dry PKL with the variation of time durations (h). It is also shown that the capacity ($C =$ AH) has been increased exponentially up to 96 h. The maximum capacity is 10.8 AH and the minimum capacity is 2.16 AH. The difference is 8.64 AH.

Figure 4b shows the variation of capacity ($C =$ AH) for fresh PKL with the variation of time durations (h). It is also shown that the capacity ($C =$ AH) has been increased almost linearly up to 96 h. The maximum capacity is 19.2 AH and the minimum capacity is 2.4 AH. The difference is 16.8 AH.

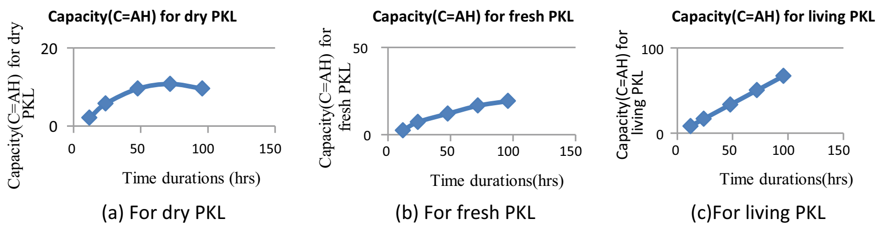


Fig. 4 Variation of capacity (C = AH) for dry PKL, fresh PKL and living PKL with the variation of time durations (h)

Figure 4c shows the variation of capacity (C = AH) for living PKL with the variation of time durations (h). It is also shown that the capacity (C = AH) has been increased linearly up to 96 h. The maximum capacity is 67.2 AH and the minimum capacity is 8.4 AH. The difference is 58.8 AH.

Figure 5a shows the energy input with the variation of energy input. It is shown that for a unit PKL electrochemical cell firstly the output and input energy is proportional and then constant and then after directly proportional and finally constant up to 10 h. Figure 5b shows the variation of energy output with the variation of time duration (h) for 10 h. It is shown that the energy output decreased linearly and slowly.

Figure 6a shows the variation of PKL energy efficiency with the variation of energy output for 10 h. It is shown that there is a correlation between output and input energy for PKL electrochemical cells. The efficiency is proportional to the energy output. Figure 6b shows the variation of PKL energy efficiency with the variation of time duration for 10 h. It is shown that the Columbic efficiency decreased linearly up to 10 h. Figure 6c shows the variation of PKL voltaic efficiency with the variation of time duration for 10 h. It is shown that the voltaic efficiency decreased up to 5 h linearly and then decreased exponentially up to 10 h. Figure 6d shows the variation of PKL Columbic efficiency with the variation of time duration for 10 h. It is shown that the Columbic efficiency decreased linearly up to 10 h.

Figure 7a shows the variation of heat rate with the variation of energy output. It is shown that the heat rate is always constant with the variation of energy output for 10 h. Figure 7b shows the variation of heat rate with the variation of time duration up

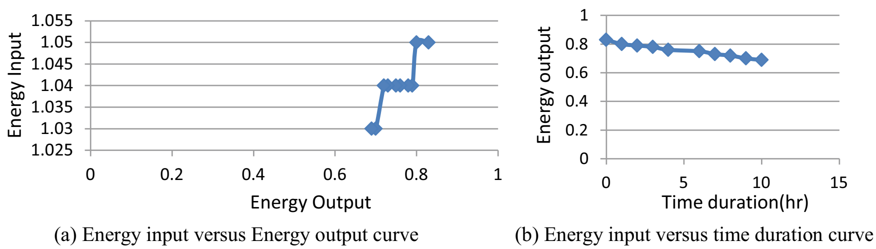
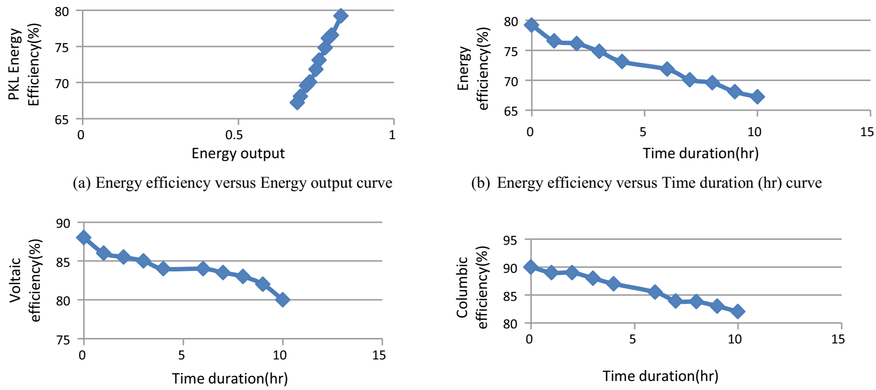


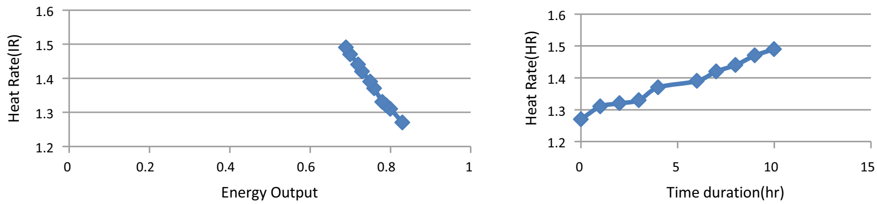
Fig. 5 Energy input versus energy output and time duration curve



(a) Energy efficiency versus Energy output curve (b) Energy efficiency versus Time duration (hr) curve

(c) Voltaic efficiency versus Time duration (hr) curve (d) Columbic efficiency versus Time duration (hr) curve

Fig. 6 Energy, voltaic and Columbic efficiency versus energy output and time duration (h) curve

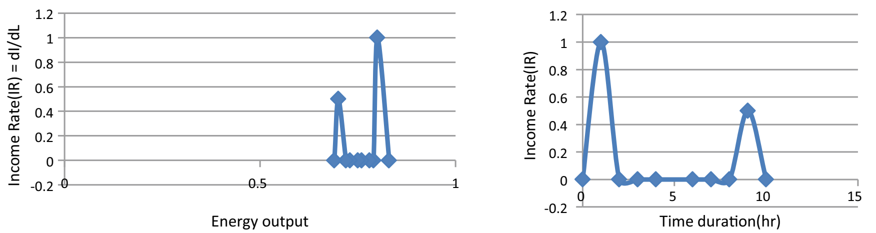


(a) Heat Rate (HR) versus Energy output curve (b) Heat Rate (HR) versus time duration curve

Fig. 7 Heat rate (HR) versus energy output and time duration curve

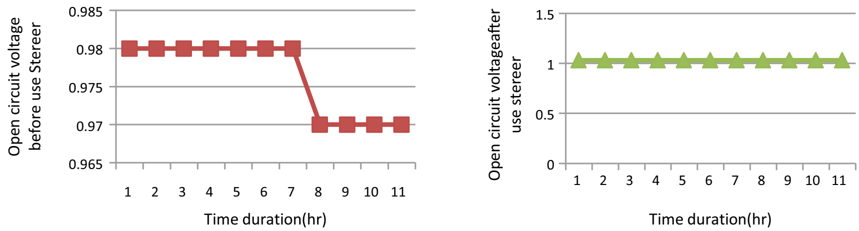
to 10 h. It is shown that the heat rate increases linearly with the variation of energy output up to 10 h.

From Fig. 8a shows the variation of income rate (IR) with the variation of energy output for 10 h. It is shown that the income rate varies with the variation of change in energy output. From Fig. 8b shows the variation of income rate (IR) with the variation of time duration for 10 h. It is shown that the income rate varies with the



(a) Income Rate (IR) versus Energy output curve (b) Income Rate (IR) versus time duration (hr) curve

Fig. 8 Income rate (IR) versus energy output and time duration (h) curve



(a) open circuit voltage versus time duration before use stirrer

(b) open circuit voltage versus time duration after use stirrer

Fig. 9 Variation of open-circuit voltage with the variation of time duration (h) using before and after magnetic stirrer with hot plate

variation of change in time duration. The variation is fluctuated with time duration up to 10 h.

From Fig. 9a, it is shown that variation of open-circuit voltage with the variation of time duration (h) using before magnetic stirrer with hot plate. It is shown that the voltage was constant up to 6 h and then after it has been decreased by 0.97 V from 0.98 V. Whereas From Fig. 9b, it is shown that the open-circuit voltage was constant for 10 h. The reason behind that due to applied magnetic oscillation the filtered PKL extract became more acidic.

4 Conclusions

- The obtained short-circuit current for living PKL tree is maximum among three conditions
- The obtained short-circuit current for dry PKL is minimum among three conditions
- The maximum capacity was 67.2 AH for living PKL tree
- The minimum capacity was 2.16 AH for dry PKL
- The living PKL tree is better than the other two conditions dry PKL and fresh PKL
- The performance of the PKL cell increases after making oscillation of the PKL extract by magnetic stirrer with hot plate.
- Some Performance and operation characteristics of the PKL electrochemical cell like input–output curves, efficiency curves, heat rate and incremental curves have been conducted.

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