SMART ENERGY DISTRIBUTION AND CONTROL SYSTEM INTEGRATION

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ABSTRACT

In today's era the world of automation is emerging as the fast developing technology in all the fields of engineering. Smart city is the main aim to be achieved in near future. Smart city comprises of many developing steps such as smart building, smart vehicles, and smart roads etc. This paper has dealt with features of smart building which constitutes one dimension of smart city. The first and foremost thought about smart building leads to the energy consumption by it. In our smart building project, we are going to promote the sustainable development and usage of renewable energy resource so that it has less impact on the environment in terms of pollution. Hence, Smart Energy distribution plays a significant role to increase the efficiency of the inverter-battery connected system and also it can be utilized effectively in remote areas where there is interrupted power supply during load shedding from grid is available to houses.

Keywords: Arduino Uno, Battery Cycle, Renewable Energy Resources, Smart Energy Distribution, Solar Photovoltaic system.

I INTRODUCTION

Countries across the globe promote the usage of Renewable Energy Resources, to reduce the carbon emission and make world a better place to live in. Over the next 20 years the world's demand for energy consumption is expected to grow exponentially. India is the world's third largest energy resource consumer. Here solar energy is utilized in various forms like solar heater, cooker etc. [1]. Electricity is only available to 25% of the population; still approximately 300 million of people are not able to access it [2].

According to facts about 6,000 million GWh energy potential lies within India itself per year. The "National Solar Mission" aims about 20 million solar lighting systems, 20,000 Mega Watt (MW) grids Solar Power (SP), 2,000 MW of off-gridas well as 20 million square meters "solar thermal collector" under process is expected to be fulfilled by 2020. According to the newest apprise of the MNRE, 2 GW landmark "grid-connected and off grid systems combined" Solar establishment has been crossed in India. As on 31st October 2013, the overall solar mounted capacity stood about2219 MW. Among that "grid-connected" solar capacity was 2080 MW whereas "off-grid" systems were 139 MW [3]. Hence as it is abundantly available with maximum benefits, these days' energy generation through Solar is promoted for sustainable development.

"Buildings and residential homes will be a vital part of such a smart as they are central energy consumers and living and working area of the city residents" as mentioned in [4]. One of theproblems associated with the Solar Photovoltaic Systems (SPV) connected in the smart building is the inefficient usage of battery. Usually in every house today inverter–battery systems are established to avoid black out during power cut but there are regions where power-cut occurs once in a week or twice. The life of the battery degrades because it's charging and discharging cycle is not maintained.

A research was conducted on the Solar Photovoltaic residential system where its design and management was taken into consideration to maximize the saving in the electricity bill [5]. The battery cycle per day was taken into account to calculate its life and efficiency. Another research on grid connected Solar Photovoltaic residential system was performed where the software "Hybrid Optimization Model for Electric Renewables (HOMER)" was used for the analysis and design of a residential power system. Economic conditions of standalone system and grid connected system were compared. Again the life of battery was considered on the basis that it is being used for 24 hours [6]. In both the papers discussion about the Inverter – Battery system which are not used on daily basis are discussed. Even the degradation of battery if its normal charge/discharge cycle is not maintained is mentioned.

Hence, in this paper the designed and developed system enhances the life of the battery, i.e. smart energy distribution system discussed in detail in the following section. It even supports the efficient usage of Solar Energy by charging the battery according to the available supply. This system can be even deployed in the rural areas whereinterrupted power supply from the grid is available to prevent black out and promote usage of Renewable Energy Resources.

II PROPOSED WORK

1.1 Smart Energy Distribution System

Energy distribution and management system consecutively are not diversely available in the market. Even it's not economic for the consumers. As the usage of Solar in conversion of energy is increasing rapidly so a stabilized controller is the foremost requirement.

Microcontroller (AT Mega 328) deployed in Arduino Uno, a Smart Controller is being employed to monitor and control the energy distribution. Thus shown in the Fig.1 is the Functional Block Diagram of the Smart Energy Control and Distribution system.

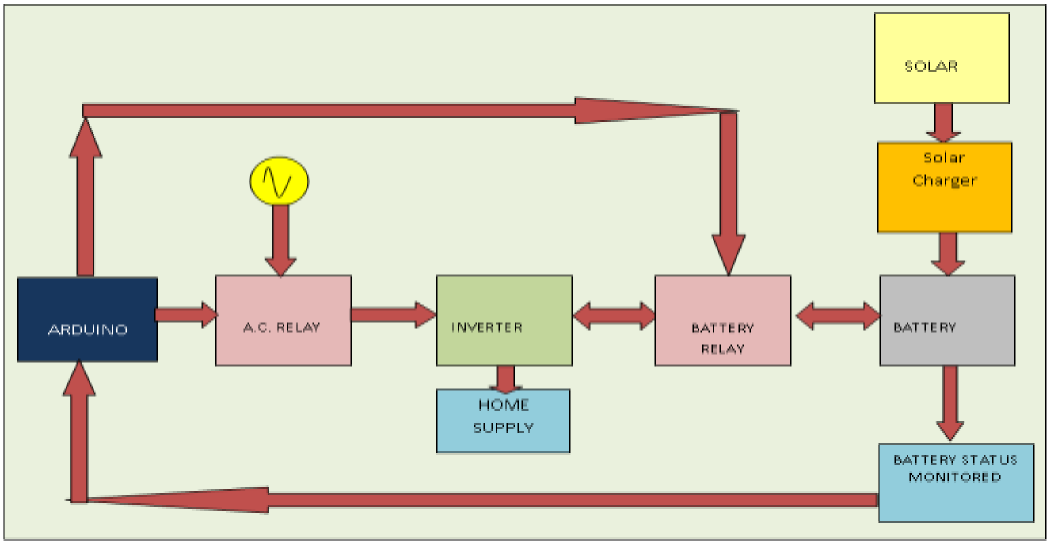

Fig. 1: Functional block diagram

According to the Fig. 1 the components employed in the system are 5V operated A.C relay, Inverter- Battery Pack, 5V operated DC relay and 100 W, 40V operated 2- Solar Panel's connected with Solar Chargers. The logic employed to control the above described components is mentioned in the Table no. 1.

Table 1: Energy distribution control logic

S.No.	Truth Table		Action
	Battery Relay	A.C Relay	
1.	0	0	1.Battery is being charged by Solar Energy. 2.No supply.
2.	0	1	1.A.C supply available. 2.Battery is being charged by Solar Energy.
3.	1	0	1.Battery being charged only by solar energy. 2.Supply available only from battery (Battery Discharging), no A.C supply available.
4.	1	1	1.Battery is being charged both from Solar Energy and A.C supply. 2.Supply available from A.C mains (Battery Charging).

From the above table it is seen that two relays A.C & D.C play a prominent role in controlling the various components of the circuit. From the table first condition depicts that Battery is getting charged with the help of available Solar Energy in the day time and the connection between inverter and battery is disconnected with the help of battery relay. In the second condition though the household appliances are working on the available A.C supply but still it is not being utilized for the charging of battery.

Battery is still only being charged with Solar Energy available in the day time. In the third condition Battery is getting charged and discharged simultaneously as the A.C supply is not available and only Batter is the source of energy consumption by load. In the last condition Battery is being charged simultaneously with the A.C supply and Solar Energy. This can be the case when the Solar Energy is not totally available to fully charge the battery.

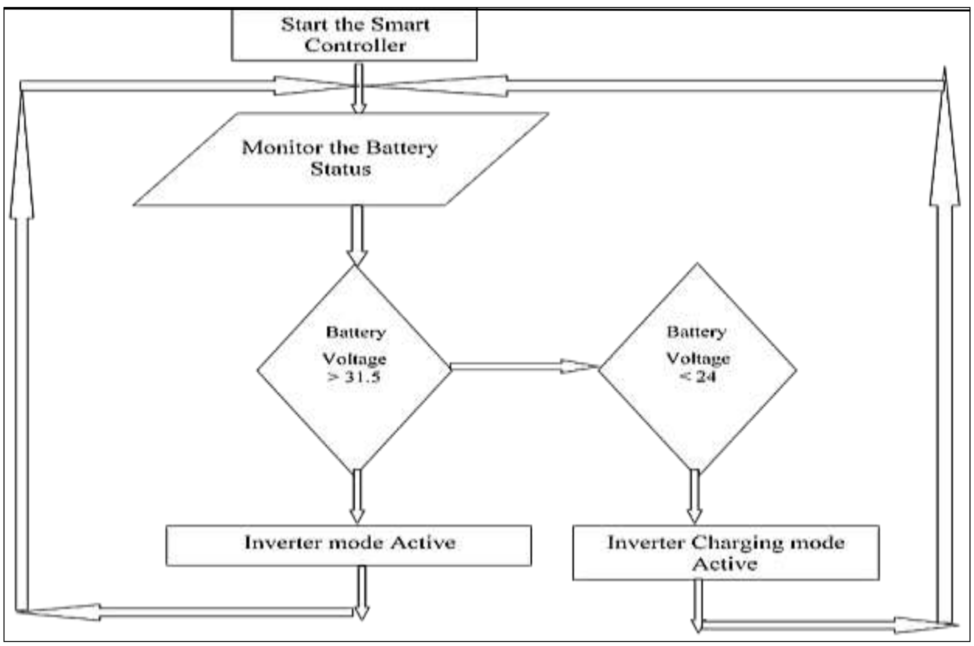

Fig. 2: Energy monitoring and control flowchart

Basically the A.C relay is connected between the Inverter and the A.C supply available from the grid. It works on the logic shown in the Fig. 2 which illustrates that when the smart controller starts functioning, the monitoring of the voltages of 2-Solar Panel and that of battery pack takes place. According to this continuous monitoring if the battery voltage rises above 31.5V then the A.C relay gets cut off and the building load is managed by the Inverter-Battery Pack system. As soon as the voltage rises below the 24 V supply then the A.C relay goes back to normally closed position. And the charging of the battery starts taking place.

Now the logic employed to make use of the Solar Energy and reduce the grid supply consumption is that when the battery gets discharged during night time it does not revert back to charging instead when the solar energy is available in the morning it then starts charging the battery. The software used for monitoring the voltages continuously is Cool Term shown in Fig. 3. It is used to fetch the data from the serial port of the Arduino Uno and then display the values. It even stores these values in the text file with the date and time as shown in Fig. 4 so that for future reference graph can be plotted.

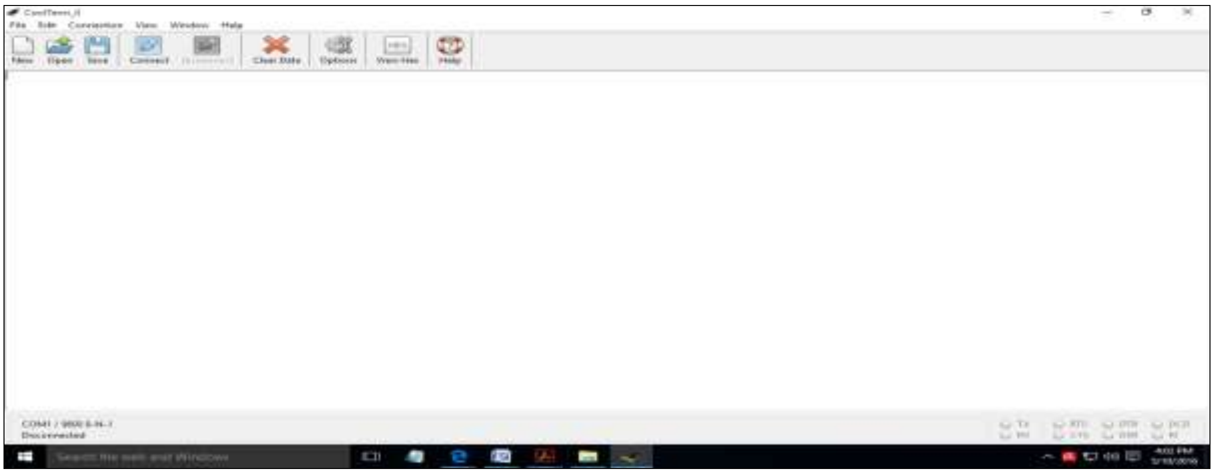

Fig. 3: Window of Cool Term monitoring software

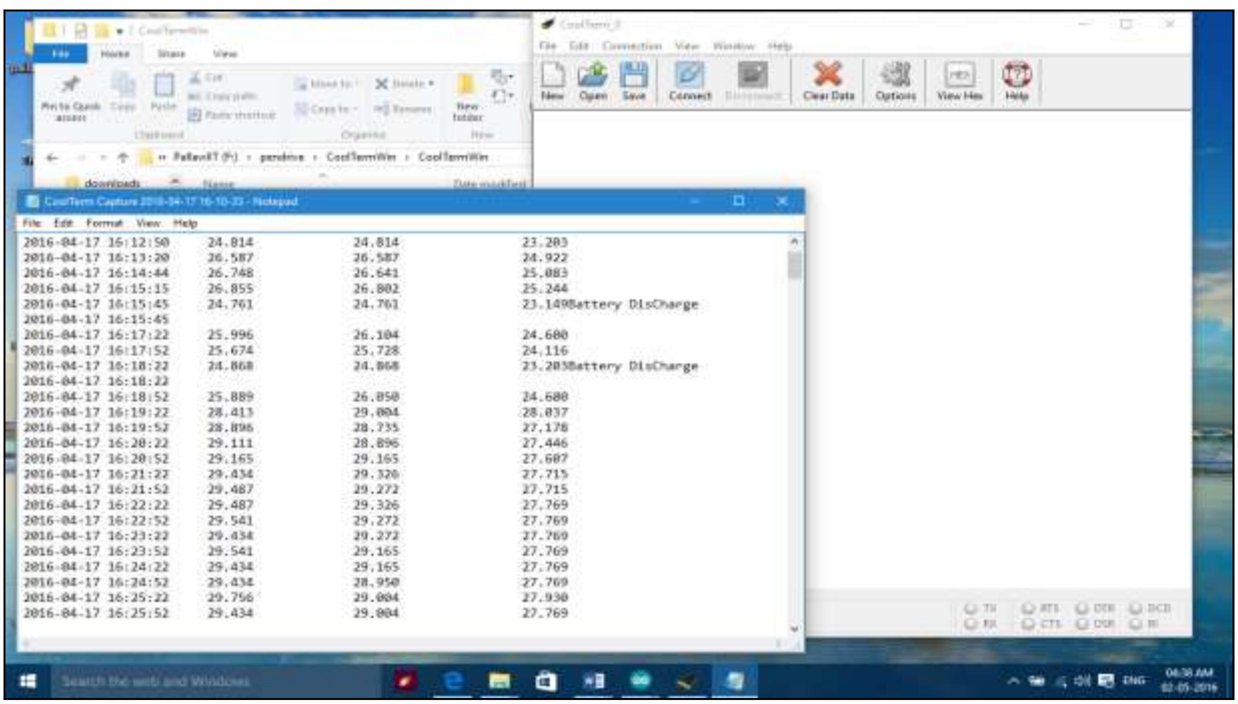

Fig. 4:Window showing the display of monitored values in text file

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2.2 Charge/ Discharge cycle of battery pack

In charge cycle of battery pack (BP), electrical energy (EE) is converted into chemical energy (CE). BP will hold this converted CE. Discharge cycle is a reverse process of charge cycle i.e. CE is converted back to EE. Upper limit of BP during its charge cycle is kept at 31.5V. Lower limit of BP during its discharge cycle is maintained at 24V. To study behavior of these cycles of BP, three observations sets of Solar Energy, AC supply and BP were taken and are discussed as shown in Fig. 5.

2.2.1 Solar Energy cycle

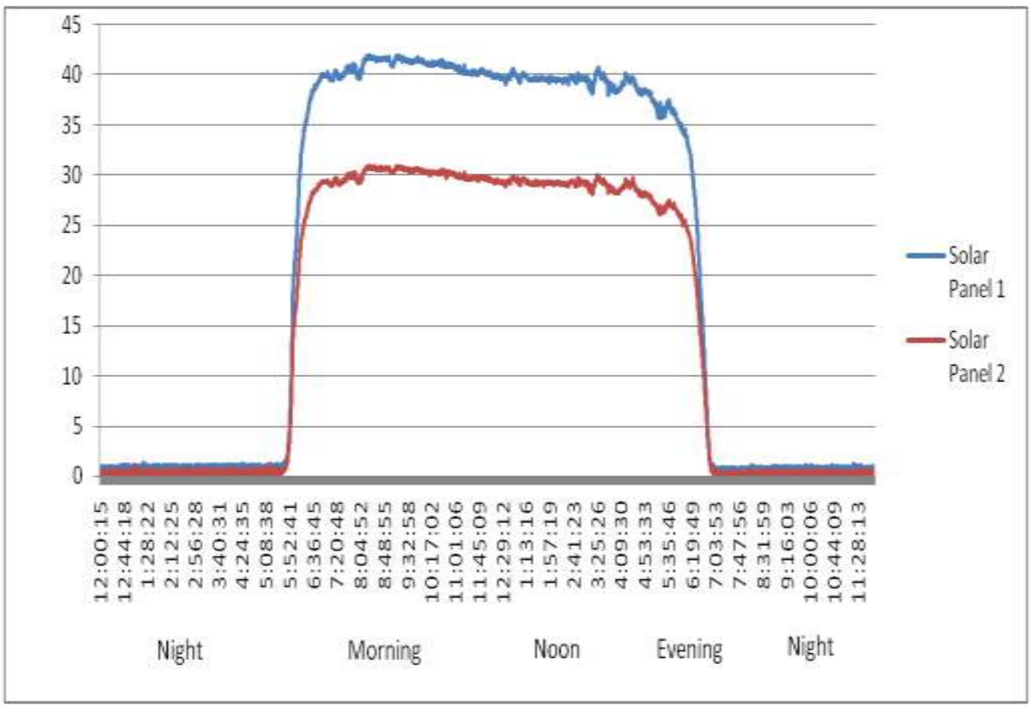

Fig. 5: Availability of Solar Energy in 24 hours (Dated: 02-04-2016)

Observations taken on April 2, 2016 show that sufficient SE is available from 6:30 a.m. to 6:20 p.m. for charging the BP. Peak voltage value obtained from first PV module is approximately equal to 40V and from second PV module is 30V. From 7:00p.m. to 5:00a.m. SE is not available.

2.2.2 Battery discharge cycle

A standard load of 200w was used to discharge the BP up to 80% (DOD) of its rating. Before point "B", BP is 100% charged and its open circuit terminal voltage is 31.7V. On applying load of 200w a sudden drop in voltage to 27.5V level was observed and discharge cycle of BP was started. At point "A" shown in Fig. 6 charge level of BP reaches its DOD level and discharge cycle has to be terminated for better battery life. Discharge cycle of BP started at time 8:38 and ended at time 13:08 i.e. it takes four and a half hours to discharge the BP at a rate of 200W up to safe level.

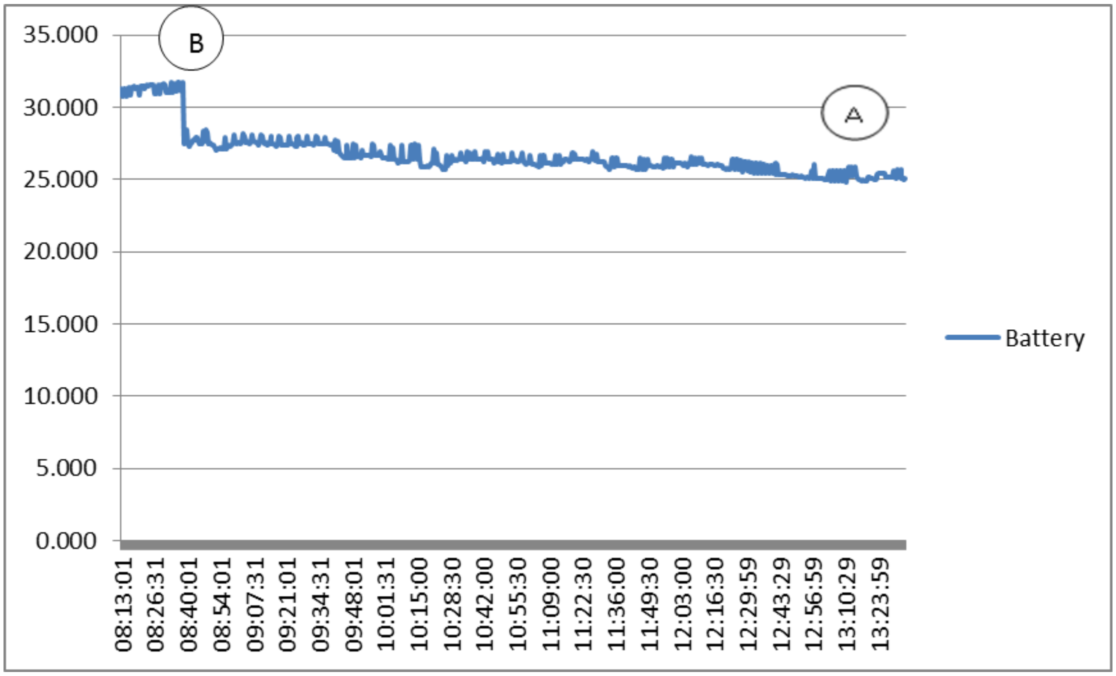

Fig. 6: Battery discharge cycle (Standard Load=300W)

2.2.3 Battery discharge parallel with SE charge

BP discharge cycle gets prolonged when executed in parallel with solar charging cycle. It takes six hours to discharge the BP at a standard load of 200w. The performance is enhanced by one hour and thirty minutes. The duration between point “A” and point “B” shown in Fig. 6 is the above mentioned discharge time period.

It means SE has generated 450W of EE or CE in six hours. Thus one can say that Solar Panels existing in the developed system have generated 75W of energy per hour. Out of 200W energy of Solar panel, as per its specification, generation or availability of 75W energy demonstrates poor performance of system. Its various causes are maximum point tracking error, higher resistance value of connecting wire, 25W energy consumption by the Solar Charge Controller etc. Freely available 75W energy still has significance.

2.2.4 BP charge cycle with AC supply

In Fig. 7 charge cycle of BP is shown with AC supply. It takes six hours to charge it completely. For it one has to pay money. Thus it must be avoided as possible but not at the cost of services provided by the system. Hence to avoid the charging of the battery in the night- time smart logic has been developed to start the charging of the battery when the solar is available in the morning hours.

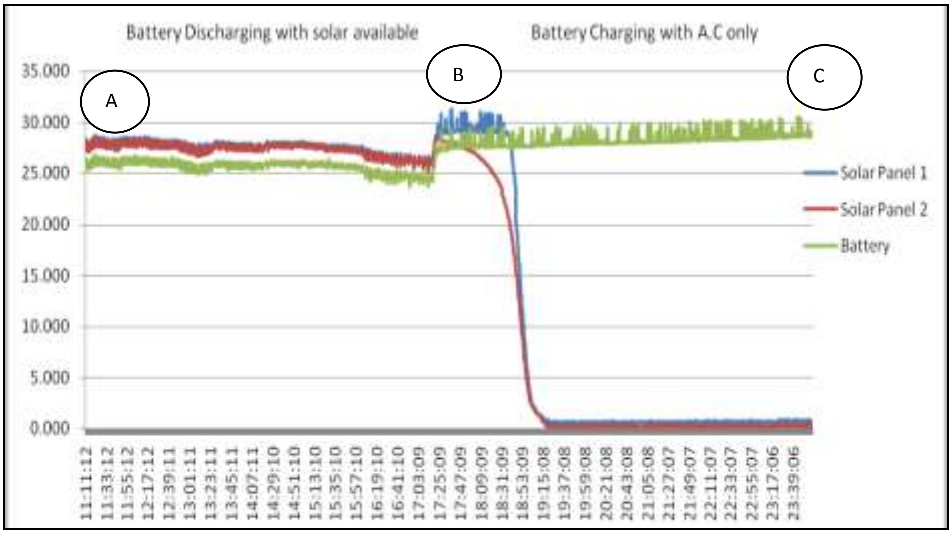

Fig. 7: Discharging of battery pack and simultaneous charging with Solar Energy

III CONCLUSION

In this research work smart energy distribution system was designed and developed which enables the user to save their energy consumption. This smart controller helps in maintenance of battery and solar panel by continuously monitoring its state. The charge/discharge cycle of the battery is maintained with this battery's health and efficiency is improved. No special inverter-battery system setup is required. Instead existing setup can be used to store the Solar Energy and used accordingly. This setup can also be used in rural areas to prevent black out and provide backup during the load peak hour cut off period. There is scope of future research which can be carried out to improve the battery efficiency by experimenting with different type of battery and load and further on the basis of the weather conditions smart distribution of the load can be achieved.

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