Design of solar parking lot for 20 electric vehicles in St.John's NL

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***Abstract*— This paper discusses the design of a solar parking lot in the off-grid mode for charging 20 Electric vehicles for Newfoundland condition. The selected site is near the Canada National Research Council (NRC) building located in the Memorial University of Newfoundland St. John's, Newfoundland, Canada. Smart EQ ForTwo was considered as the electric vehicle (loads) for the design. For the selected site, a system is optimized using homer software. The proposed charging infrastructure is equipped with current sensors that communicate the power generation data and power consumption data in real-time to the cloud for direct PV run or utilize the excess power stored in the battery bank. The decision is made to charge the connected EV using an algorithm that makes use of the data, sent by the sensors with the help of IoT. Complete system design and simulation results are presented in the paper.**

Keywords—PV, Electric Vehicle (EV), Renewable energy, IoT (Internet of Things), solar energy.

I. INTRODUCTION

In this fast-changing world, Renewable energy resources such as solar systems can help meet the fast-growing energy demand. Further EV is a reliable alternative for conventional vehicles given its technical and environmental advantages.[1][2] However, renewables are intermittent in nature. Hence the need of backup support comes in play; a battery pack is added to system to aid in supplying uninterrupted power to load even when the power produced by PV was not sufficient to meet the load's energy demand. The car taken into consideration is Smart EQ ForTwo with 17.6kW lithium-ion battery pack. IoT (Internet of Things) plays a crucial role in handshake with the physical layer or the field level devices – current sensor. IoT gives these sensors the ability to transfer data over the internet. All the decisions taken in the system are executed in the cloud with the help of an algorithm.

The role of the current sensor is to measure the current that is being used up, power being produced, and being stored at this point of time and publish the data to the cloud for the algorithm to act upon. This information comes handy when the algorithm tries to measure the power generated by the PV panel versus the power demand of the home loads versus power stored. In this situation, the data generated and published is used as a reference to make the decision, either direct PV run or battery-based power. [3]

By default, the system operates primarily on power produced by PV until there is a need for the battery to supply power.[4] When the battery reached 30% of its SOC, the system stops working.

In this paper, we designed a system to address this issue by implementing solar parking lot for 20 cars. The sizing of the system was executed with the help of Homer.

II. SITE DETAILS AND CALCULATIONS

A. Selected Site

Parking lot is located next to Canada National Research Council (NRC) building in the Memorial University of Newfoundland, St. John's, Newfoundland, Canada. With a total area of 7,350m^2.

B. Site's solar insolation from NERL website

For the selected site the clearness index is between 0.39 to 0.49 with an average of 0.44 and solar insolation varying between 1.28 kWh/m^2/day to 5.14 kWh/m^2/day with average of 3.15 kWh/m^2/day. Figure 1 illustrates the solar radiation and clearness index for selected site in St. John's, Newfoundland, Canada.[5]

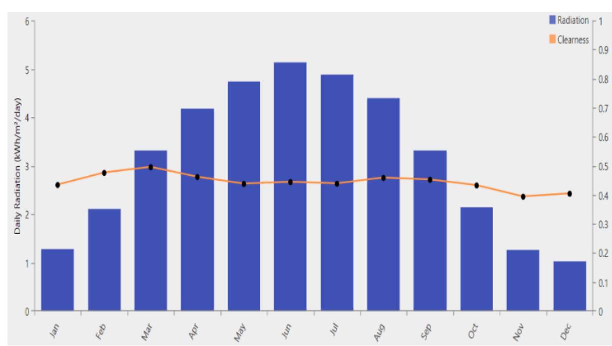

Fig 1 – Solar insolation and clearness index of selected site.

C. Site's load calculation

The system is required to supply 20 vehicles with 2.3 kW each, for a duration of 9 hours, hence we expect the daily load profile to be a constant, straight line.

$$\text{Peak Load} = \text{Power per vehicle x number of vehicles}$$
$$= 2.3kW \times 20 = 46\ kW$$
$$\text{Total Load} = \text{Peak Load x number of duty hours}$$
$$= 46 \times 9 = 414\ kWh/day$$

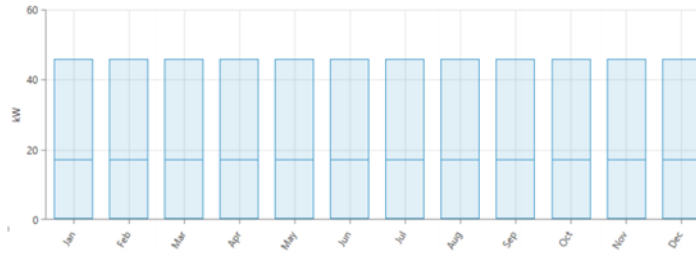

Fig 2 – Annual power requirement of the selected site from HOMER

D. Site's Photovoltaic panel area caluclation

Average daily sunlight in St. John's = 1633 h for 272 days, where h is hours.
Power output = energy usage per day/number of full sun hours per day

$$= \frac{414\frac{kWh}{day}}{4.47} = 92.617\ kW$$

For PV sizing considering derating factor as 0.8

= power output / derating

$$= \frac{92.617}{0.8} = 115.771\ kW$$

PV size array = Total calculated capacity of PV / Wattage of one panel

For calc power output

$$\frac{92617\ \mathrm{W}}{340\ W} = 272\ \mathrm{Modules}$$

For derating factor

$$\frac{115771\ \mathrm{W}}{340\ W} = \ 340.5 \sim 340\ \mathrm{Modules}$$

Area Calculation

For desired power output

272 x 1.88 = 511.36m^2

Including derating factor

340 x 1.88 = 639.2m^2

Available area = 7,350 m^2

Bus voltage = 240 VAC

For desired power output, number of strings = 28 Strings

Number of panels in each string = 10

Voltage output = 240 V per string

Including derating factor the number of strings = 34 Strings

Number of panels in each string = 10

Voltage output = 240 V per string

Figure 3 represents the schematic of the proposed system in homer software. Canadian solar CS6U – 340M is used as the PV panel, Tesla Power Wall 2.0 is considered as the battery, 50 kW inverter and the load profile comes to 414 kWh/d with 46 kW as the peak. With the help of Homer, the system size for the selected site is calculated.

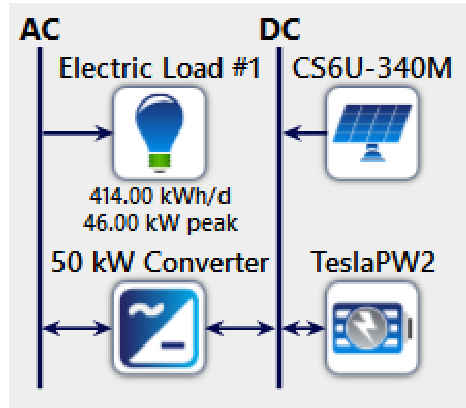

Fig 3 – Homer schematic of the proposed system

III. Methodology

The incorporated system includes a PV system which is the primary source of power for the system, a converter to aid charging the battery and inverter to convert the stored power to power the load. When the PV system lacks power to meet the load's power requirement the battery reels power to meet the load's power requirement. Figure 4 illustrates the block diagram of the proposed system. The system is designed for 4 cases.
Case 1: Power produced by PV panels are directly used for powering the load. In this case only loads using up all the power produced. [6] Figure 9 illustrates the implementation of case 1 in algorithm.
Case 2: Power produced by PV system is HIGH and load's energy demand is met. Excess power is passed onto battery charger or converter to aid battery charging. Figure 6 illustrates the implementation of case 2.
Case 3: Power produced by PV system is LOW, load's energy demand is not met. Battery shares the stored power to meet the load's energy demand. Figure 7 illustrates the implementation of case 3.
Case 4: Batteries SOC drops to 30% or less the system breaks from battery and it stops reeling power from battery till the SOC of battery is more than the threshold. Figure 9 illustrates the implementation of case 4 in algorithm.

A. Photovoltaic panel

Solar CS6U 340M which outputs 340 W and is of 1.8 m^2 in area is considered for this design.

B. Battery

Tesla Powerwall 2.0 was selected as battery for the application. The calculation for battery is as follows with 3 days of backup. Therefore, from calculations 216 batteries are required.

Wh/day	= 414000 Wh/day
3 days	= 414000 x 3 = 1242000 Wh
40% DOD	= 1242000 / 0.4 = 3105000 Wh
Temp Cons (>80F)	= 3105000 x 1 = 3105000 Wh
Ah cap of Bt bank	= 3105000 / 240 = 12937.5 Ah
Number of Batteries	= 12937.5 / 60 = 215.6 ~ 216 Nos.

C. Inverter

An inverter is considered for the design with 50kW output capacity as the peak load value comes to around 46kW. The inverter in this case is a single-phase inverter. Figure 5 illustrates the inverter circuit diagram.

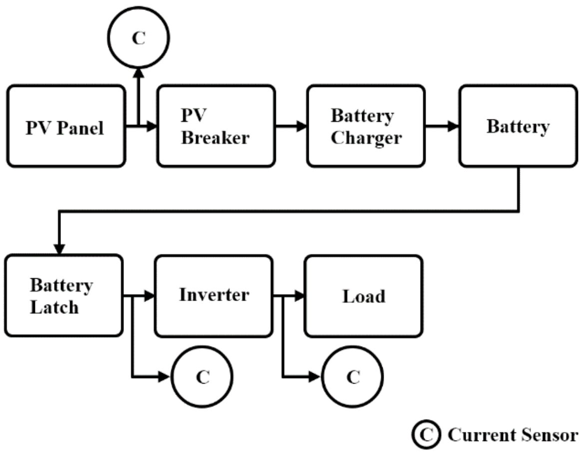

Fig 4 – Overall block diagram of proposed design

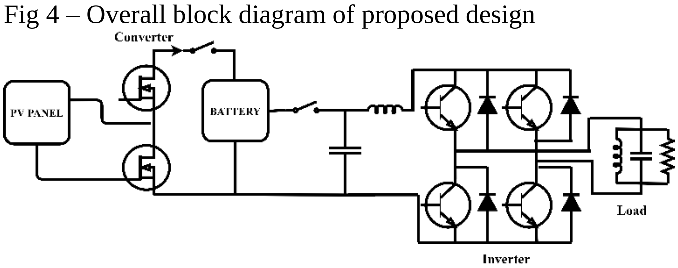

Fig 5 – Circuit diagram of proposed system design.

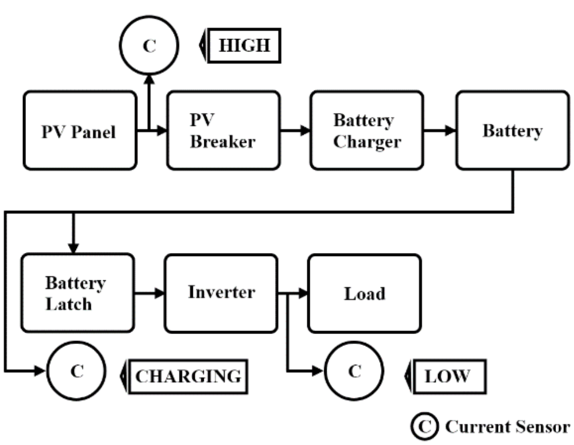

Fig 6 – Smart sensor implementation in the proposed system – Case 2

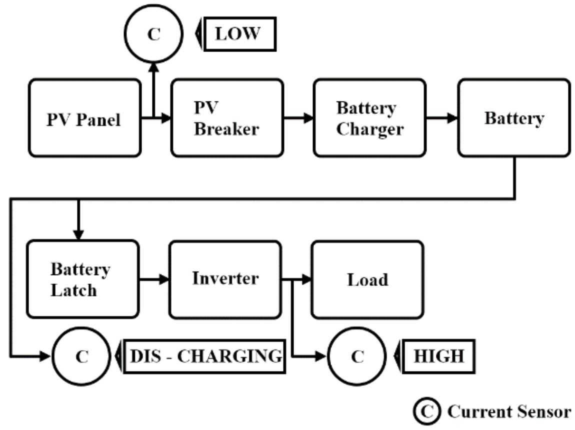

Fig 7 – Smart sensor implementation in the proposed system – Case 3

D. Smart EQ ForTwo – Electric Vehicle (Load)

Smart EQ ForTwo with 17.6kW lithium-ion battery pack and 4.6kW onboard charger is considered in this design. The charging rate considered is 12 km/hr at 230v and 10A.

To verify an algorithm was developed for the system implementation.

IV. ALGORITHM

The developed algorithm runs on cloud and IoT helps in transferring data generated by current sensors in real-time to the cloud [7]. Figure 8 illustrates the flowchart of proposed algorithm. The algorithm measures the Produced power from PV, load's power usage, batteries SOC, Voltage and current and sends the generated information to cloud, which acts as input to the algorithm. The algorithm works as follows – as the load's energy demand rises and falls the change in load values by a difference of 2 values triggers a post-call to the sensor that in turn pushes the data to the server. The server on receiving the push request checks the power production data from the PV panel, SOC of the battery to make the decision either to continue direct PV run or get support from battery.[8] Battery on reaching 30% of SOC the sensor triggers a post request and pushed the data to server. The algorithm on receiving the push request breaks the circuit till the SOC of the battery reaches more than the set threshold. [9][10] Figure 9 illustrates the current sensor implementation in the proposed system. The algorithm checks for the change in value published by each sensor having information on real-time values on load's energy demand, PV power generation and SOC of battery. PV logic loop and SOC logic loop take care of the direct PV run, battery run or critical stop of system till the SOC of battery reaches a value more than the threshold. The PV production and SOC decision block controls the breaker and is the decision maker for the system to run either on direct PV run or on battery or to a critical stop. The feedback of the decision is sent to the cloud and the loop keeps executing. This system is implemented in cloud to make sure that it can operate autonomously and as an initiative towards smart grid.

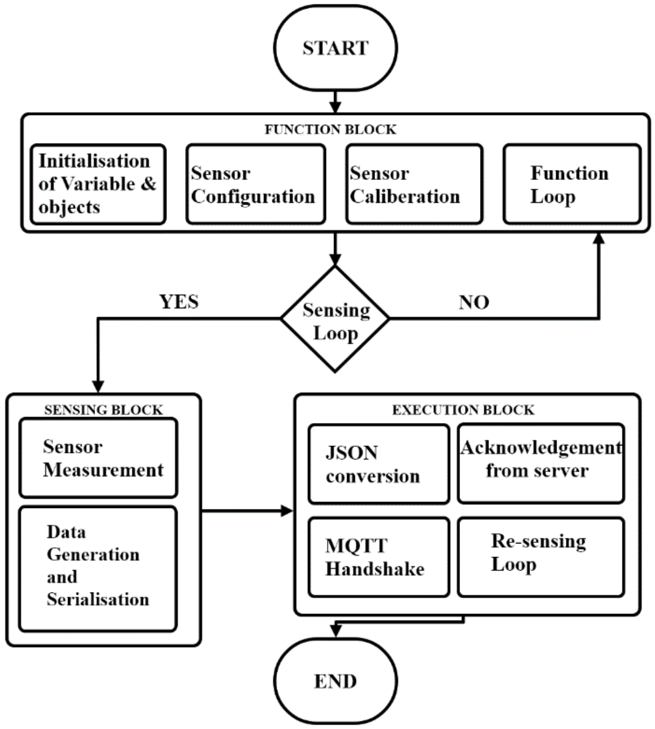

Fig 8 – Flowchart of proposed algorithm.

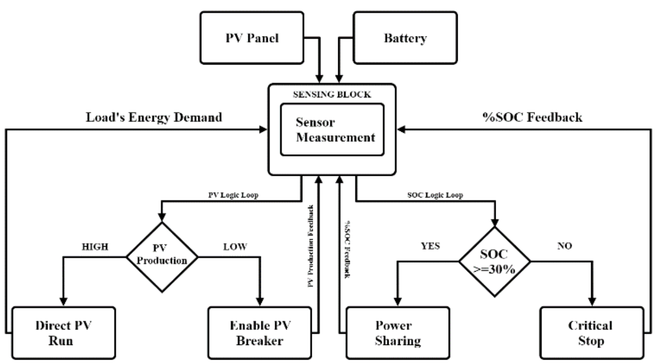

Fig 9 – Current sensor implementation in the proposed algorithm

V. Conclusion

The solar parking lot for 20 cars in St. John's, Newfoundland was successfully designed. From figure 1 solar irradiation index is 3.15 kWh/m2/day, number of PV panels used were 340W modules producing 115.771 kW which are placed in 34 strings with 10 panels in each string. A commercially available inverter of 50 kW capacity was incorporated with 216 Tesla Power Wall 2.0 batteries each of 240 V and 60 Ah. Regardless, the current sensors played a major role in generating and transferring data to the cloud with the help of IoT. The system was successfully designed and the algorithm being the driving factor for the system, runs on cloud by utilizing the data transferred by the current sensor with the help of IoT. The major advantage of this designed algorithm is the scalability – can be extended from one parking lot to citywide parking lots.[11] [12] The algorithm also gives insights on load consumption at any point of time in the day. The idea behind implementing the algorithm in the cloud was to emphasis an initiative towards a smart grid. This algorithm will act as an application layer that gives insights on load utilization of one parking lot, or several parking lots in a locality or of a city. Further research would be directed towards scheduling charging routines for the EV, extending this project the concept of V2X can be implemented in the designed algorithm. Where forecasting and scheduling would be established based on usage pattern for charging and discharging to meet the energy demand of a building or a locality or a city. [13][14][15]

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