EV Charging Station Design with PV and Energy Storage Using Energy Balance Analysis

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***Abstract*— Electric Vehicles (EVs) have the potential to provide numerous ancillary services to the grid owing to the fact that they can act as either loads or sources when connected to the grid. However, customers are still disinclined to embrace this technology because of long battery charging time, limited range, and high battery replacement costs. Widespread rollout of fast Electric Vehicle Charging Stations (EVCS), however, could solve these shortcomings as they make services readily available for them and work as the stimulus for the future growth. Seemingly, reliability of those services by EVCS depends upon the optimum design of it, since over-dimensioning may render it as uneconomical or conversely, technically unreliable for the case of under-dimensioning. In this paper, an algorithm is developed for optimum sizing of Photovoltaic (PV) panel, Battery Energy Storage System (BESS) and Grid Transformer for an EVCS circumscribed by the grid constraints.**

***Index Terms*-- Charging Station (CS), Electric Vehicle (EV), Time Series Energy Balance Analysis.**

I. INTRODUCTION

Electric Vehicles (EV) are becoming center of attractions as the substitute of conventional fossil fuel vehicles as the formers are less liable to Green House Gases (GHG) emission. However, they will exert more stress by drawing a very high current on the already optimized power grid, which are not yet thoroughly prepared for it [1]. Besides, given the technology is at early stage, no robust and worldwide consistent standards have been devised yet, which may hinder the expected growth of it. However, despite the deficiencies in terms of lack of standards, EV have the promise to alleviate requirements of dedicated Battery Energy Storage System (BESS), which in turns paves the way to integrate more renewable based Distributed Generation (DG) to grids, e.g. - PV or wind, for minimizing intermittency and supporting emergencies [2].

Even with the numerous advantages from the grid point of view, customers are still reluctant to embrace this technology due to long battery charging time, limited range, and high battery replacement costs [3]. The problem is compounded manifold by the scarcity of Electric Vehicle Charging Station (EVCS). For overcoming the problem, rollout of EVCS at appropriate locations is of paramount importance [4]. But then again, even if they are put in huge number, they cannot always support the customer's requirements owing to the grid constraints like voltage, current and power limits. Therefore, other sources like solar, wind and energy storage system must be deployed for minimizing blocking probability of EV in an EVCS [5].

Under the blocking probability constraints, in [5] the sizing procedures for local storage system have been given so that the customer satisfaction is guaranteed. In [6], the authors designed a docking station for solar charged electric and fuel cell electric vehicles. They found that, with identical PV panels charging time is different for different types of battery. In [7], the optimum design procedures of an EV/PHEV charging station with DC bus and storage system have been described. Their results show that, the power ratings of an EVCS can be reduced by determining it from the average demand instead of peak demand. The authors in [8] proposed the charging station battery as the countermeasures for surplus energy storage; though, they did not discuss on the optimum dimension of the battery system. In [9], a mathematical model have been derived for measuring the required storage capacity in kWh with a given power supply capacity and given load. In [10] the ratings of a super-capacitor and flywheel in a fast charging station have been optimized though, other types of storage were not taken into account. In [11], the authors have suggested PV, wind power as the possible cleaner sources of energy in an EVCS, and described a process for determining battery storage, energy trade framework back and forth to the grid, from PHEV charging trend and level of uncertainty. The authors in [12] have analyzed the techniques of optimizing EVCS components by a queuing system considering investment, operational costs, and suitability of the storage system.

Although, a litany of works have been carried out on optimum sizing of the components of EVCS, but state of charge (SOC) of battery energy storage system (BESS), loss of energy, loss of load, utilization of BESS, utilization of grid transformer, maximum permissible yearly grid buy energy, maximum permissible yearly grid feed in energy etc. have not been taken into account altogether for dimensioning PV panel, BESS and grid transformer size. This paper is aimed at dimensioning these components subject to those factors mentioned earlier. As already been said, most of the previous works have taken only few of the key performance indicators (KPI) into account for dimensioning only one or two important aspects of an EVCS. Whereas, this paper considers different KPIs for gauging three very important quantities (BESS size, PV size and transformer size) of an EVCS altogether- which is the main contribution of this paper.

The rest of the paper is organized as follows. Section II gives a detailed formulation of methodology used for this work. Results and discussions are presented in section III and section IV presents the conclusions.

II. Methodology

In the proposed EVCS, with solar energy, the generated energy from PV panel shall satiate the load exerted by the convoy of EV. Certainly, the generated energy shall not always be exactly equal to the load as both generation and load are stochastic in nature. Consequently, in a given time of the day, energy may be supplied from other sources or may run surplus. The most convenient source of aforementioned required energy could be the ubiquitous national grid. Nevertheless, the location of EVCS in the grid, the size of grid transformer, grid dynamics etc. put limits on the amount of power and energy that could be drawn from the grid. Therefore, a good portion of load could be left discarded. Likewise, the surplus energy could be injected back to grid if all the grid conditions are fulfilled. Thus, all those constraints could lead to the situation of surplus energy being discarded hence loss of benefits. Both the adversities can be addressed by putting a Battery Energy Storage System (BESS) of appropriate size at the EVCS. In that case, the surplus energy shall charge BESS, and the BESS shall supply required energy instead of the grid under apposite conditions e.g. State of Charge (SOC). Again, the BESS cannot absorb all the surplus energy and neither can supply the additional required energy at all the time. As a result, energy will still be transferred back and forth between the grid and the EVCS, though the amounts shall be much lower, which will lead to a smaller size of transformer.

Suppose, the sample of solar irradiation is taken at every Δt hour (could be fraction or integer) and the sample number is denoted by i. Then, the power generated by PV panel for the i-th sample can be given by (1).

$$P_{PV}(\mathrm{i}) = I_r(\mathrm{i})\,\mathrm{A}\mathrm{e}_{PV} \tag{1}$$

where, P_{PV} (i) is the power generated by PV for i-th sample, I_r (i) is the solar irradiation (kW/m^2), A is the area of PV panel (m^2) and e_{PV} is the annual average efficiency of PV. If it can be assumed that the average generated power shall remain same for the whole of the time Δt and equal to P_{PV} (i) then in time series of generated power, time as the ordinate and generated power as abscissa, the area under the curve represents the total energy, which can be written as (2).

$$E_{PV}(\mathrm{i}) = P_{PV}(\mathrm{i})\Delta\mathrm{t} \tag{2}$$

where, E_{PV} (i) is the generated energy from PV for i-th sample for the whole time interval of Δt. In every Δt, different types of EV will arrive at EVCS and they will exert different amount of power. The average power at i-th sample will be the product of the average number of EV and the average power of those EV. Considering the average number of EV for whole of time interval Δt is equal to the i-th sample and with the similar assumptions made earlier for the PV time series and area under curve, EV energy can also be determined as in (3).

$$E_{EV}(\mathrm{i}) = P_{EV}(\mathrm{i})\Delta\mathrm{t} \tag{3}$$

where, E_{EV} (i) is the energy required for EV at i-th sample for the time interval of Δt. As mentioned earlier, E_{EV} (i) and E_{PV} (i) will very seldom be equal to each other and therefore, energy will either be required from other sources or be rendered surplus as in (4). If the value of E_{SR} (i) is positive then energy remains surplus; likewise, remains short of requirement for negative values. These scenarios are depicted in (5).

$$E_{SR}(\mathrm{i}) = E_{PV}(\mathrm{i}) - E_{EV}(i) \tag{4}$$

$$E_{SR}(i) = \begin{cases} E_S(i), \ldots\ldots\ldots\ldots\ldots\ldots\forall\ E_{SR}(i) > 0 \\ \text{-}E_R(i), \ldots\ldots\ldots\ldots\ldots\ldots\forall\ E_{SR}(i) < 0 \end{cases} \tag{5}$$

where, E_{SR} (i) is the energy required or surplus on top of the PV energy at i-th sample. E_S (i) is the surplus energy and E_R (i) is the required energy at i-th sample. At the beginning, E_S (i) will charge BESS and E_R (i) will be supplied from the grid until a minimum energy state (e.g.-SOC) is attained by BESS. Once minimum energy state is achieved, E_R (i) will be first supplied from BESS and remainder of it will be supplied from the grid. Likewise, E_S (i) will charge battery until maximum energy state is reached and will be fed to the grid thereafter. Let, B is the maximum BESS capacity in kWh, E_{Bm} is the minimum energy state to be maintained in BESS and E_B (i) is the available energy in BESS at i-th sample. Then, constraints for BESS could be given by (6) and the charging energy of BESS can be quantified as the product of E_S (i) and efficiency of charging as in (7). Making similar assumptions, one can easily write energy equation for discharging process as in (8).

$$E_{B\mathrm{m}} \le E_B(\mathrm{i}) \le B \tag{6}$$

$$E_{BC}(i) = E_{BC}(\mathrm{i}-1) + e_c E_S(i) \tag{7}$$

$$E_{BD}(i) = E_{BD}(\mathrm{i}-1) + E_R(i)/\mathrm{e}_D \tag{8}$$

where, E_{BC} (i) and E_{BD} (i) are the energy of BESS at i-th sample during charging and discharging respectively, E_{BC} (i-1) and E_{BD} (i-1) are the energy of BESS at (i-1)-th sample during charging and discharging respectively, and e_C and e_D are the efficiency of charging and discharging of BESS respectively. When charging, the BESS energy always must be less than or equal to the maximum BESS energy as in (9). Putting the value of E_{BC} (i) from equation (7) in equation (9) and rearranging one can get (10). During the discharging, one can easily achieve the equations (11)-(12). With all these constraints, one can write the energy equation of BESS as (13).

$$E_{BC}(\mathrm{i}) \le B \tag{9}$$

$$E_B(\mathrm{i}-1) \le B - e_C E_S(i) \tag{10}$$

$$E_{B\mathrm{m}} \le E_{BC}(\mathrm{i}) \tag{11}$$

$$E_{B\mathrm{m}} + E_R(\mathrm{i}) / \mathrm{e}_D \le E_B(\mathrm{i}-1) \tag{12}$$

$$E_B(i) = \begin{cases} E_B(i-1) + e_C E_S(i), ...\forall\ E_S(i) > 0 \cap E_B(i-1) \le B - e_C E_S \\ E_B(i-1) - \dfrac{E_R(i)}{e_D}, ...\forall\ E_R(i) > 0 \cap E_{Bm} + \dfrac{E_R(i)}{e_D} \le E_B(i-1) \\ E_B(i-1), ... else \end{cases} \tag{13}$$

The drawbacks of (13) are that the BESS will not be fully charged or fully discharged. Because, when charging, once the energy reached equal to or greater than B – e_C E_S (i), the BESS will stop taking any further charge. In other word, BESS does not accept a fraction of E_S (i), rather it absorbs the whole of it. Similar situation also occurs for discharging process. Subsequently, for solving the aforementioned problem (13) can be rewritten as (14). For determining the energy that may be injected back to the grid and loss of energy for the case of BESS being fully charged, transformer is overloaded as well the total energy injection limit being violated, one may assume that the transformer size is denoted by T and total energy injection limit is by E_{ITI}. Then the injected energy E_I (i) and lost energy E_{LE} (i) can be given by (15) and (16), when E_S (i) > 0 and E_B (i-1) ≤ B – e_C E_S (i) for all the conditions for both the equations.

$$E_B(i) = \begin{cases} \forall\ E_S(i) > 0, \\ \begin{cases} E_B(i-1) + e_C E_S(i), ...\forall\ E_B(i-1) \le B - e_C E_S(i) \\ B, ... else \end{cases} \\ \forall\ E_R(i) > 0, \\ \begin{cases} E_B(i-1) - \dfrac{E_R(i)}{e_D}, ...\forall\ E_{Bm} + \dfrac{E_R(i)}{e_D} \le E_B(i-1) \\ E_{Bm}, ... else \end{cases} \end{cases} \tag{14}$$

$$E_I(i) = \begin{cases} \forall\ E_{IT}(i-1) + e_T[E_S(i) - E_B(i) + E_B(i-1)] \le E_{ITI} \\ \begin{cases} e_T T, ...\forall\ E_S(i) - E_B(i) + E_B(i-1) > 0 \\ e_T[E_S(i) - E_B(i) + E_B(i-1)], ... else \end{cases} \\ \forall\ E_{IT}(i-1) + e_T[E_S(i) - E_B(i) + E_B(i-1)] > E_{ITI} \\ \begin{cases} e_T T, ...\forall\ T < E_{ITI} - E_{IT}(i-1) \\ e_T[E_{ITI} - E_{IT}(i-1)], ... else \end{cases} \end{cases} \tag{15}$$

$$E_{LE}(i) = \begin{cases} \forall\ E_{IT}(i-1) + e_T[E_S(i) - E_B(i) + E_B(i-1)] \le E_{ITI} \\ \begin{cases} 0, ...\forall\ E_S(i) - E_B(i) + E_B(i-1) \le 0 \\ E_S(i) - E_B(i) + E_B(i-1) - T, ... else \end{cases} \\ \forall\ E_{IT}(i-1) + e_T[E_S(i) - E_B(i) + E_B(i-1)] > E_{ITI} \\ \begin{cases} E_S(i) - T, ...\forall\ T < E_{ITI} - E_{IT}(i-1) \\ E_S(i) - E_{ITI}(i) + E_{IT}(i-1), ... else \end{cases} \end{cases} \tag{16}$$

e_T is the efficiency of grid transformer, and E_{IT} is the total energy sold to the grid till a given sample i and could be calculated as (17).

$$E_{IT}(i) = E_I(i) / \mathrm{e}_T + E_{IT}(i-1) \tag{17}$$

Similarly, assuming total energy purchasing limit is E_{PTI}, the purchased energy E_P (i) and lost load E_{LL} (i) can be given by (18) and (19) when E_R (i) > 0 and E_B (i-1) – E_R (i) / e_D ≤ SOC_m B for all the conditions for both the equations.

$$E_P(i) = \begin{cases} \forall\ E_{PT}(i-1) + e_T[E_S(i) - E_B(i) + E_B(i-1)] \le E_{PTI} \\ \begin{cases} T / e_T, ...\forall\ E_R(i) - E_B(i-1) + E_B(i) > T \\ [E_R(i) - E_B(i-1) + E_B(i)] / e_T, ... else \end{cases} \\ \forall\ E_{PT}(i-1) + e_T[E_S(i) - E_B(i) + E_B(i-1)] > E_{PTI} \\ \begin{cases} T / e_T, ...\forall\ T < E_{PTI} - E_{PT}(i-1) \\ E_{PTI} - E_{PT}(i-1) / e_T, ... else \end{cases} \end{cases} \tag{18}$$

$$E_{LL}(i) = \begin{cases} \forall\ E_{PT}(i-1) + e_T[E_S(i) - E_B(i) + E_B(i-1)] \le E_{PTI} \\ \begin{cases} 0, ...\forall\ E_R(i) - E_B(i-1) + E_B(i) \le T \\ E_R(i) - E_B(i-1) + E_B(i) - T, ... else \end{cases} \\ \forall\ E_{PT}(i-1) + e_T[E_S(i) - E_B(i) + E_B(i-1)] > E_{PTI} \\ \begin{cases} E_R(i) - T, ...\forall\ T < E_{PTI} - E_{PT}(i-1) \\ E_R(i) - E_{PTI}(i) + E_{PT}(i-1), ... else \end{cases} \end{cases} \tag{19}$$

SOC_m is the minimum SOC desired, and E_{PT} (i) is the total energy purchased from the grid until i-th sample, which could be calculated as (20).

$$E_{PT}(i) = E_P(i) / \mathrm{e}_T + E_{PT}(i-1) \tag{20}$$

The state of charge (SOC) is calculated as in (21) considering the charging and discharging characteristics are linear as is the case in lithium ion battery. Actual charged energy (E_{CA} (i)) and discharged energy (E_{DA} (i)) are calculated as in (22). Average utilization of BESS is calculated as in (23). Normalized energy from PV (E_{PVN}), injected energy (E_{IN}), purchased energy (E_{PN}), lost energy (E_{LEN}) and lost load (E_{LLN}) with respect to EV load are calculated as in (24), and average SOC (SOC_A) are given by (25). The utilization of grid transformer is given by (26). Here, i_{max} = max (i) = (Hours in the total time period) / Δt.

$$SOC(i) \le E_B(\mathrm{i})/B \tag{21}$$

$$E_B(i)-E_B(i-1)=\begin{cases}E_{CA}(i),\ldots\ldots\ldots\ldots\forall\, E_B(i)>E_B(i-1)\\ -E_{DA}(i),\ldots\ldots\ldots\ldots\forall E_B(i)<E_B(i-1)\\ 0,\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots else\end{cases} \tag{22}$$

$$U_B=(\sum_{i=1}^{i_{\max}}(\mathrm{E}_{CA}(i)+E_{DA}(\mathrm{i})))/(\mathrm{i}_{\max}[\max\{\sum_{i=1}^{i_{\max}}E_{CA}(i),\sum_{i=1}^{i_{\max}}E_{DA}(i)\}]) \tag{23}$$

$$\{E_{PVN},E_{IN},E_{PN},E_{LEN},E_{LLN}\}=\{\sum_{i=1}^{i_{\max}}E_{PV}(i),\ \sum_{i=1}^{i_{\max}}E_I(i),\ \sum_{i=1}^{i_{\max}}E_P(i),\ \sum_{i=1}^{i_{\max}}E_{LE}(i),\ \sum_{i=1}^{i_{\max}}E_{LL}(i)\}/\sum_{i=1}^{i_{\max}}E_{EV}(i) \tag{24}$$

$$SOC_A=\sum_{i=1}^{i_{\max}}\mathrm{SOC}(i)/\mathrm{i}_{\max} \tag{25}$$

$$U_T=[\sum_{i=1}^{i_{\max}}\{\mathrm{E}_P(i)+E_I(\mathrm{i})\}]/(\mathrm{i}_{\max}\,T) \tag{26}$$

The cost function will be the function of area of PV panel (A), capacity of BESS (B), minimum desired SOC (SOC_m), transformer size (T), total energy injection limit (E_{ITl}) and total energy purchasing limit (E_{PTl}). Loss of energy (E_{LEN}) is a very important parameter in this optimization. The minimization of it implies that one is unwilling to lose any energy from PV at the expenses of either the loss of a portion of EV load or bigger BESS size or both; whereas, the maximization means the willingness to lose energy from PV for a smaller BESS size. The cost function can be written as the summation of products of all these variables with some other weight factors as they are all normalized on a scale of one.

$$\min f_C(A,B,SOC_{\mathrm{m}},T,E_{IT1},\mathrm{E}_{PT1)})=E_{PVN}K_{PV}+(1\text{-}SOC_A)K_{SOC}+E_{LEN}K_{LEN}\ or\ (1\text{-}E_{LEN})K_{LEN}+E_{LLN}K_{LLN}+(1\text{-}U_T)K_T+(1\text{-}U_B)K_B \tag{27}$$

Here all K are the weight factors of all the variables. The values of K can be set arbitrarily and from the optimization point of view, and one can set higher weight to certain parameters than that of others. The optimization of f_C will be carried out subject to the limit constraints of variables $E_{PVN,}$ B, T, E_{ITl} and E_{PTl} as in (28)

$$(\mathrm{L})_{\min}\le L\le(L)_{\max} \tag{28}$$

where, $(.)_{\min}$ and $(.)_{\max}$ are the minimum and maximum limits of the variables respectively, and L={$E_{PVN,}$ B, T, E_{ITl}, E_{PTl}}.

III. Results and Discussions

The irradiation of Brisbane, Australia, is taken as the reference for the case study [13], and the E_{EV} requirements of University of Western Australia as in [14] is taken as reference and some degree of uncertainties are added to that data. The Ir and E_{EV} are taken at one-hour interval. It was found that the irradiation was higher during the early part and towards the end of the year, and relatively lowers during the middle of the year. The hourly EV load is relatively uniform throughout the year as a single day load is mapped into a yearly load with some randomness being put into it. The different parameters of data I_r and E_{EV} are tabulated in Table I.

TABLE I. PARAMETERS OF INPUT DATA I_r AND E_{EV}

Parameters	I_r (kWh/m$_2$)	E_{EV} (kWh)
Average	0.22	256.57
Maximum	1.096	450
Minimum	0	74
Standard Deviation	0.30	112.77
Auto-correlation	0.96	0.88

As discussed in the methodology, for optimizing cost function in (27), E_{LEN} could be either minimized or maximized. The values of K could be equal to one or different subject to individual's choice. However, shortly, it will be see that different values of K give better optimization results than the equal ones. Because, whether E_{LEN} is being maximized or minimized, any increase in E_{LLN} will have less penalty on cost function hence it will be elevated to a bigger value, which in turn will decrease the value of B. On the other hand, for $K_{LEN} >> K_{LLN}$, for minimization of E_{LEN}, B will attain a very high value in attempt to absorb all the energy as it has the higher penalty; but for maximization of E_{LEN}, the B will collapse down to smaller values in expense of higher E_{LLN} as it has less penalty. As shown in the Table II, (27) will be optimized with all five variables in (31) apart from SOC_m for the first six cases. Whereas, for the last six cases, it will be optimized for A, B and T, and all other variables to remain same constant. The values of K_{LE} and K_{LL} are assumed either one or five and rest of the values of K are assumed one. The value of SOC_{min} will remain constant at 0.4. The constraints for first six cases described by (28) are $0.5 \le E_{PVN} \le 1.2$, $0 \le B \le 50{,}000$, $0 \le T \le 1{,}000$, $0 \le E_{ITl} \le 1$, $0 \le E_{PTl} \le 1$

TABLE II. SPECIFICATIONS OF STUDIED CASES

Case	E_{LEN}	Variables	K_{LE}	K_{LL}
1	Minimize	A, B, T, $E_{ITl,}$ E_{PTl}	1	1
2	Minimize	A, B, T, $E_{ITl,}$ E_{PTl}	1	5
3	Minimize	A, B, T, $E_{ITl,}$ E_{PTl}	5	1
4	Maximize	A, B, T, $E_{ITl,}$ E_{PTl}	1	1
5	Maximize	A, B, T, $E_{ITl,}$ E_{PTl}	1	5
6	Maximize	A, B, T, $E_{ITl,}$ E_{PTl}	5	1
7	Minimize	A, B, T	1	1
8	Minimize	A, B, T	1	5
9	Minimize	A, B, T	5	1
10	Maximize	A, B, T	1	1
11	Maximize	A, B, T	1	5
12	Maximize	A, B, T	5	1

The value of E_{PVN} has been so chosen to provide at least 50% of the required energy from PV and no more than 120%. However, a high upper bound of E_{Bmax} has been arbitrarily chosen to cover all the possibilities. On the other hand, T depends on the maximum allowable size of grid transformer without desecrating the grid integrity and assumed to be 1000kW (1000/pf kVA) for these cases. Besides, the values of E_{ITI} and E_{PTI} are one, as they should not exceed E_{EV}. For last six cases, first three constraints should remain as they are but, last two constraints to turn into equality and been assigned the values $E_{ITI} = E_{PTI} = 0.25$. It means, only 25% of the required energy could be taken from the grid or injected back. The optimized values of all those mentioned variables E_{LEN}, E_{LLN}, $E_{IT,}$ and E_{PT} for all those cases are summarized in Table III for all 12 cases.

TABLE III. SUMMARIZATION OF RESULTS FOR STUDIED CASES

Case	A	B	T	E_{PTI}	E_{ITI}	E_{LEN}	E_{LLN}	E_{PT}	E_{IT}
	m^2	kWh	kW	% of Total Annual EV Energy					
1	4491	2555	145	81	54	0	10	1	0
2	4028	19119	273	92	83	0	1	50	0
3	4192	17397	279	77	42	0	0.8	50	0
4	4053	1992	146	58	47	0	11	39	0
5	8201	807	180	72	35	22	3	33	15
6	4409	7907	275	85	61	0	0.8	45	0
7	4524	2	81	-	-	4	27	25	4
8	6295	9256	258	-	-	0.3	0.5	25	1.2
9	4002	2831	84	-	-	0	26	25	0
10	4068	1911	77	-	-	0	27	23	0
11	6403	4109	260	-	-	0.8	0.5	25	2.7
12	8826	1273	2	-	-	39	30	0.5	0.2

From the Table III, it is seen that, apart from Cases 5, 7 and 12, all other cases have a very low loss of energy (E_{LEN}) as B and T are quite high for accumulating energy or injecting it back to the grid. On the contrary, for those three mentioned cases B and T are quite small. Hence, a sizeable energy is discarded. From the loss of load (E_{LLN}) point of view, Cases 2, 3, 6, 8, and 11 have values smaller than one, and remainder of the cases attained higher values. Besides, the mentioned cases also have very low E_{LEN}. Therefore, Cases 2, 3, 6, 8 and 11 could be the feasible solution. For reducing the list further, Cases 2, 3, and 6 could be omitted, as E_{PT} is very high for all the three cases with 50%, 50%, and 45% respectively. Now, it is down to Cases 8 and 11, and if one wants to maximize E_{IT} would choose Case 11 whereas, would choose Case 8 for the case of minimization. However, if one wants to choose a single case, would choose Case 11 as viz-a-viz with BESS size (B) in Case 8, it has the clear upper hand. As per the grid transformer size, both the cases have almost identical values and either one could be chosen. Comparing the best two cases from Table II and III, it is seen that, when E_{LEN} is minimized, the corresponding weight of it should be equal to the others' bar the weight of E_{LLN} (should have a higher value) and vice-versa in the case of maximization.

IV. CONCLUSIONS

In this paper, an algorithm is developed, for optimizing the size of PV panel, Battery Energy Storage System and Grid Transformer in an Electric Vehicle Charging Station (EVCS) under the constraints imposed by the grid e.g. - maximum allowable grid transformer size, maximum allowable energy that could be drawn from the grid annually and maximum allowable energy that could be injected in from EVCS to the grid annually. Numerical analysis is also done using that algorithm for pseudo-real-time electric vehicles' energy requirement and solar irradiation data for finding the optimum size of those mentioned quantities. The results show that, the algorithm with some adept optimization tweaks could accurately find the optimum values of those constituents of EVCS, which will optimize loss of load as well as the energy.

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