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Scheduling of Charging Stations to Prevent Overloading

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Abstract. Electrical Vehicles (EVs) has a promising future, technology, and impact on the environment. The exponential growth of EVs will have a massive impact on the transformers that supply the charging stations. This new challenge needs to be addressed before it becomes more sever. Simulations of the model are taken and observed to study if the transformers are overloaded; the algorithm constructed is made to control the breakers in order to avoid overloading. The primary side of the transformer would be connected to the grid and the secondary side would be connected to the two CSs. Scopes are placed to record the outputs of the transformer, CSs, and EV then the data is analyzed to better improve the algorithm for different scenarios. After simulating the transformer once with a full capacity and another overloaded, the algorithm was able to close at the desired state of charge (SOC) and open at the desired SOC.

INTRODUCTION

A new challenge is on the rise, and that is electric vehicles (EVs). EVs are starting to be more common in first world countries and that causes many challenges, because charging stations (CSs), must be introduced in order to accommodate the EVs. One challenge is that distribution transformers are being overloaded in peak hours which results in the CS to fail in charging the EVs [1]. Formulating an algorithm to have a booking system for every EV in order to avoid the overloading challenge, by sending the EVs to different CSs. With the hard work needed and the knowledge to learn from this project, it is really inspiring to be part of the new positive change that is happening to the world, a big step to reduce air pollution and make the experience of an EV better that having a normal car by introducing new technology in the car and securing a position and have no waiting time to recharge the EV. With less than five hundred thousand EVs were sold in 2015 to just above three million EVs sold in 2017 worldwide. This exponential growth of EVs being used, the management of EVs and CSs is extremely important. Figure 1 shows an example of a typical charging station every hour [2]. Many researched in order to avoid overloading by using an algorithm to schedule EVs or smart charging[3-7], and others tried to optimize the transformer, made a smart transformer concept, having two factors of penetrations levels, and even charge money as a penalty[8-10].

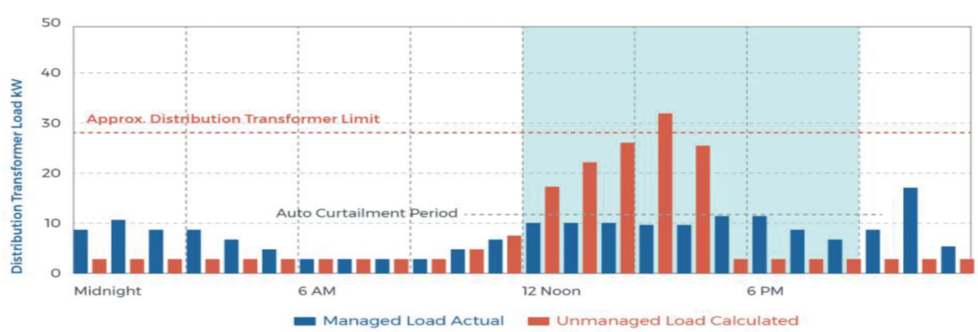

FIGURE 1: Load of a Typical Charging Station every hour (Global EV Outlook 2018, 2018**).**

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The effect of the transformer on the EVs under the charging station loading is explored in this work. The purpose is to observe, record, analyze, and compare both scenarios, were the first scenario is to charge the two EVs while the transformer is not overloaded, and the second scenario is to charge both EVs while the transformer is overloaded. Figure 2 illustrates the model used by infographics, which includes the output of the grid, transformer, two charging stations, and two electrical vehicles.

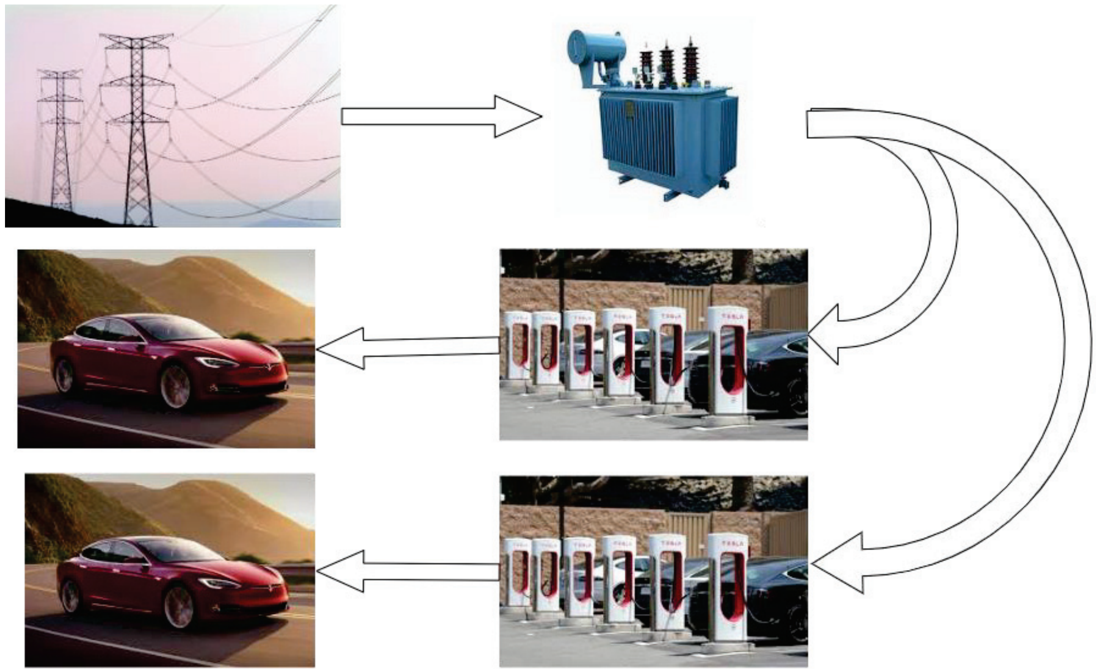


FIGURE 2: Infographic of the model.

MODELLING OF THE CHARGING STATION

As shown above in Figure 2, modelling started with a basic and general representation of the current model. As more research was done, a more extensive and more detailed model was constructed in SIMULINK. It began with the CS, after knowing the input of the CS it led to setting the parameters of the transformer and the output of the simulated grid, Figure 3. Vienna Rectifier with PFC Controller is the charging station being used in order to charge the EVs in the model [11] as shown in Figure 4.

The algorithm that takes place during the simulation takes the state of charge of both EVs and according to the satisfied condition the breakers would open and close by outputting a signal, zero or one. The logic behind this code is like a truth table, if both conditions are met then the breaker would close.

Inputs

SOC1 (State of Charge of EV 1)

SOC2 (State of Charge of EV 2)

Outputs

B1 (Breaker 1) with an initial condition is of being open (0)

B2 (Breaker 2) (Initial Condition is 0)

Loops

If SOC1 is below than 40.02%, breaker 1 would close

If SOC2 is below than 40.03%, breaker 2 would close

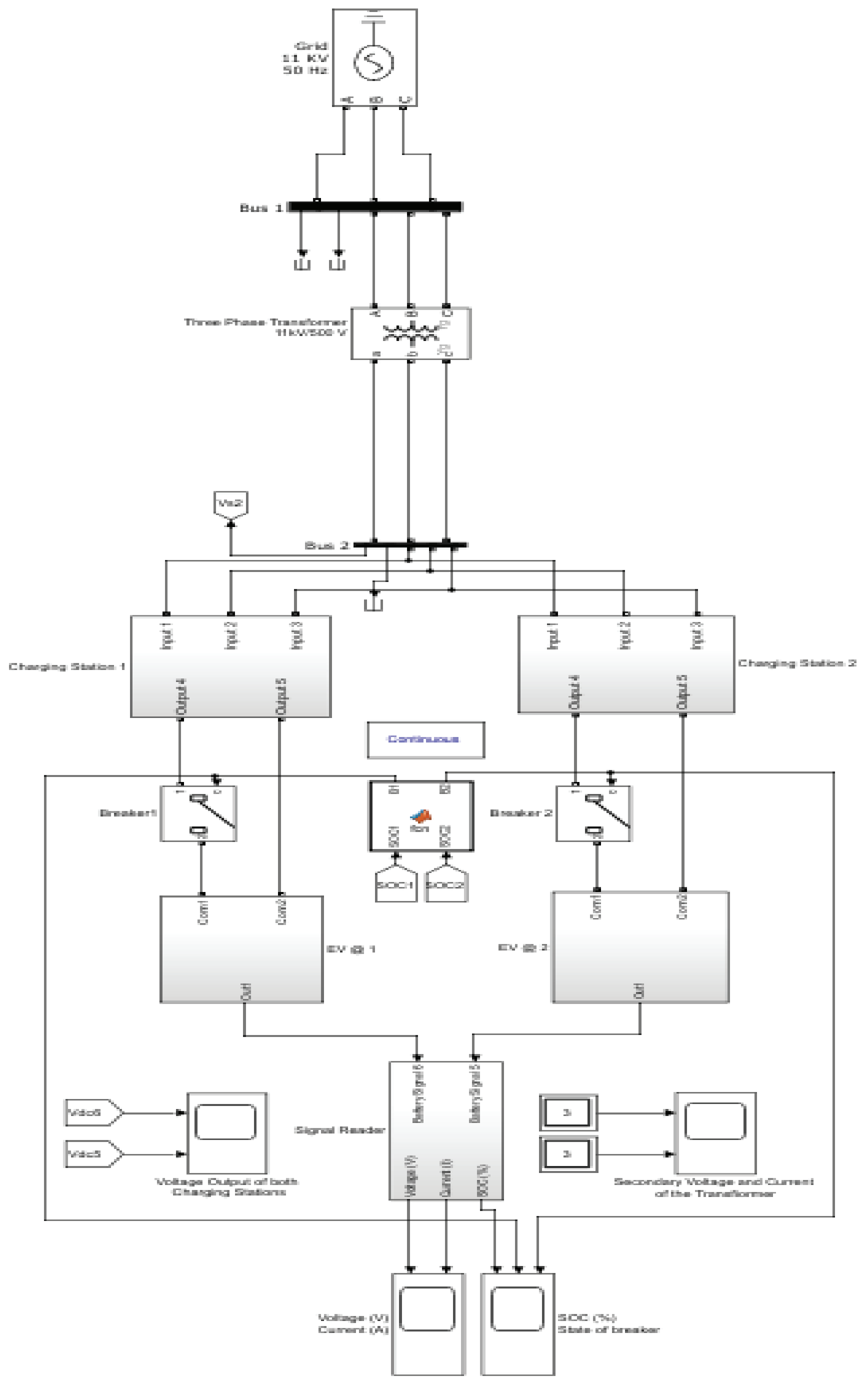


FIGURE 3: Grid connected Charging Station.

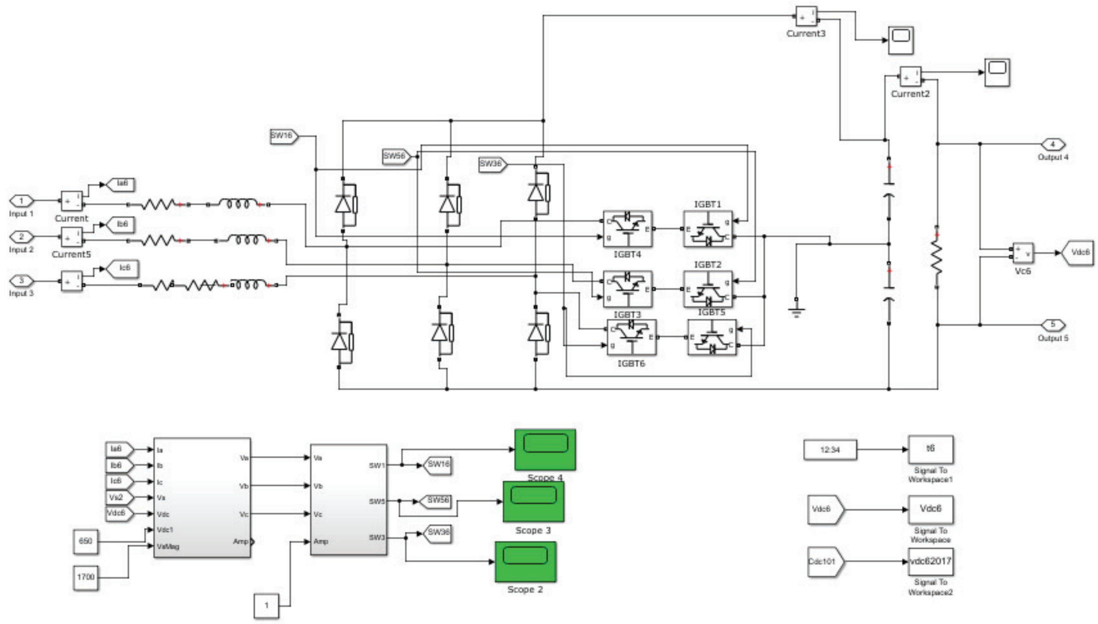


FIGURE 4: Vienna Rectifier with PFC Controller [11].

An algorithm is a code that has a set of parameters, conditions, and calculations used to solve a problem or a set of problems. For this project, scheduling of electric vehicle to charge in a charging station is achieved to avoid overloading of the transformer. A set of parameters are set in place to ensure that the overloading of the transformer is avoided, the parameters that are taken into consideration are the SOC for each EV, capacity for each battery, capacity for the two transformers, and the state of each breaker. As the algorithm is set as an AND truth table, if both conditions are met then the set command would operate. The algorithm would constantly evaluate the SOC of the battery and the capacity of the transformer, and if the parameters are met, the respective breaker will close to start charging the battery. The parameters are as follows: if the state of charge is below 40.002% and the capacity of the transformer is above 20 kVA the respective breaker would close, and the algorithm would calculate the new capacity of the transformer. A pseudo code is as follows:

1. if the SOC-1 <= 80% and TC-1 >20 kVA
2. Then close breaker 1

Appendix C is the second algorithm that integrates both transformers. For that algorithm a scenario is analyzed, where the charging stations that are connected to transformer 1 is at full capacity, the algorithm would suggest charging when the charging stations that are connected to transformer 2. Figure 3.11a shows general model of the CSs. Figure 3.11b shows the model constructed in SIMULINK. A pseudo code for the second algorithm is as follows:

1. if the SOC <= 80% and TC-1 > 20 kVA
2. Then Close Breaker 1
3. elseif the SOC <= 80 % and TC-2 > 20kVA
4. Then Close Breaker 6 (every CS has 5 slots)

(TC = Transformer Capacity)

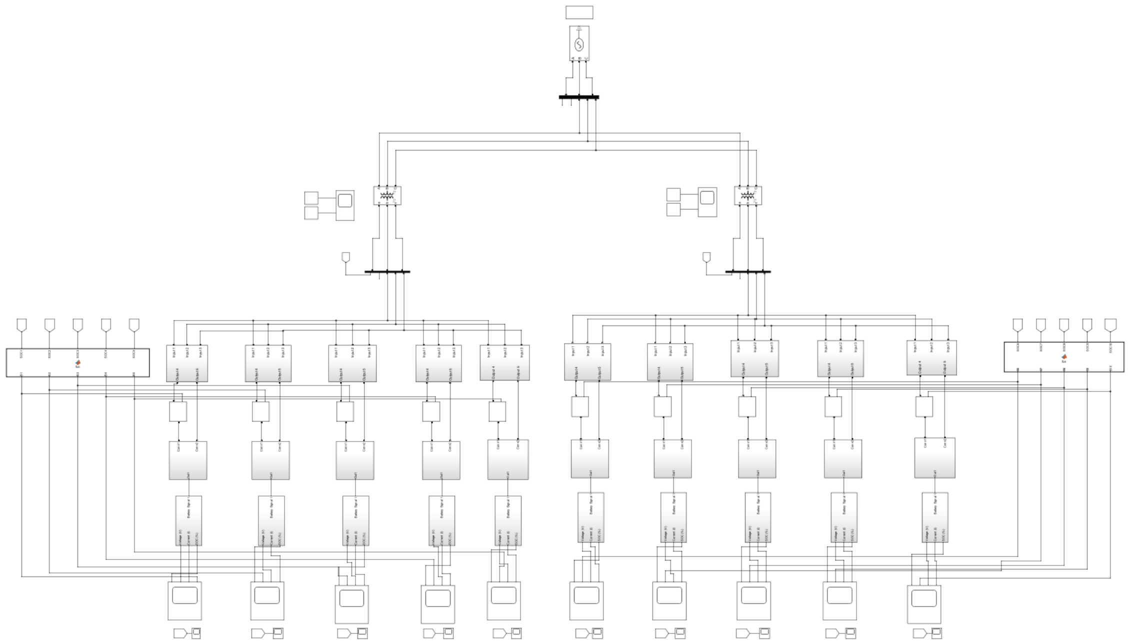
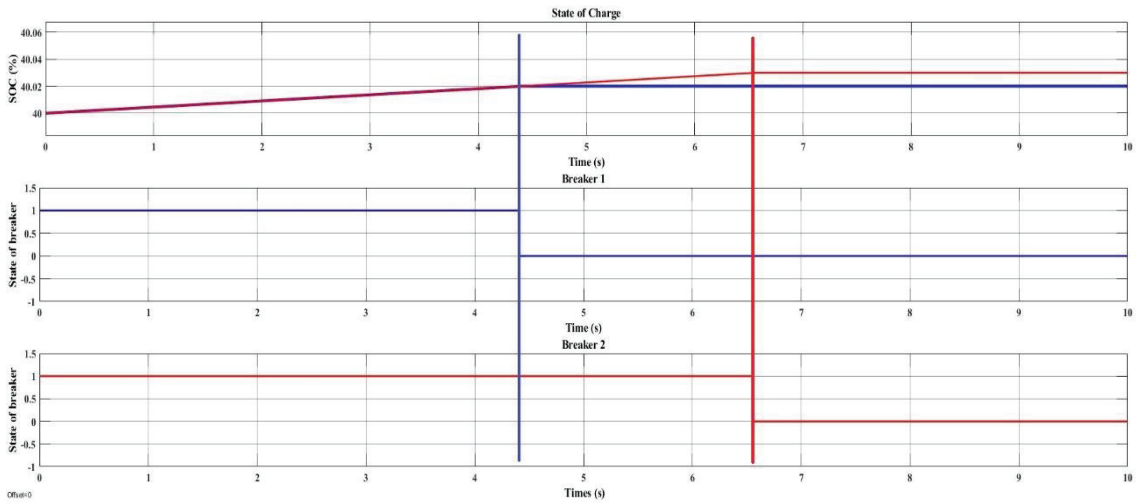


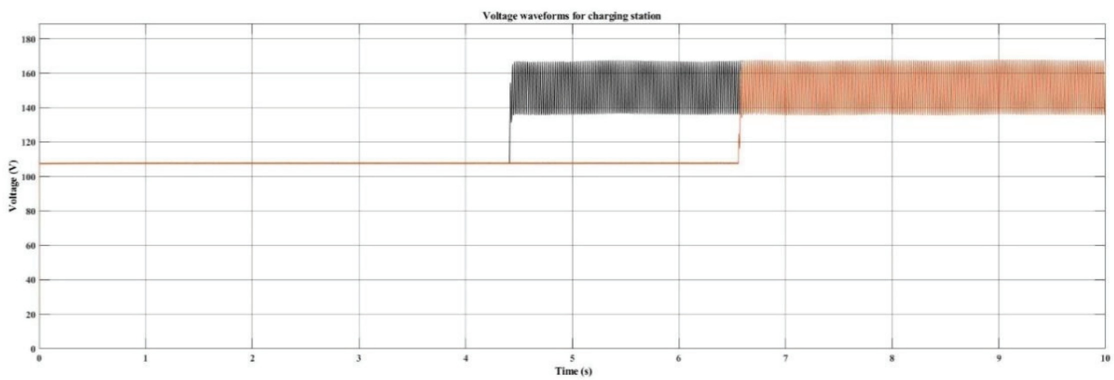
FIGURE 5: Charging Station Model

RESULTS AND DISCUSSION

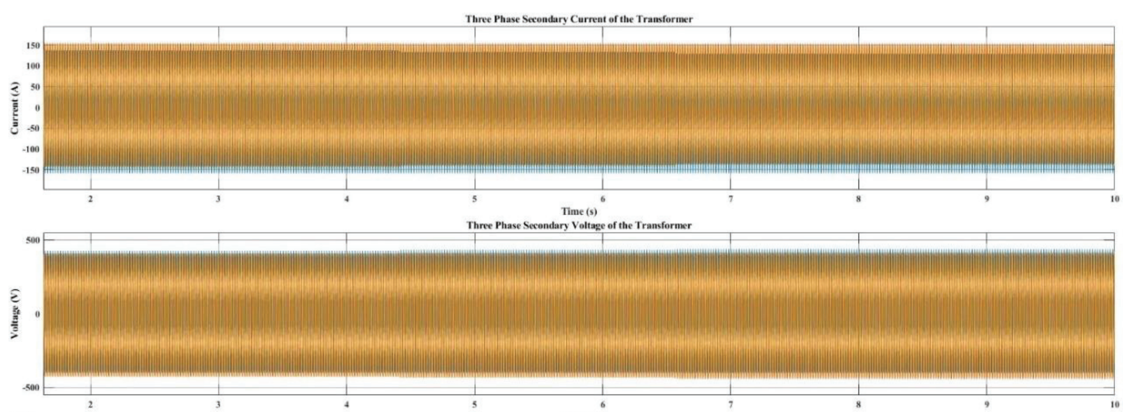
Running the model in Figure 2, which includes the algorithm with the state of the transformer at full capacity 10 seconds as shown in Figure 6(a), resulted in the SOC of the first batteries, in blue, needed approximately 4.4 seconds to reach from 40% to 40.02% and the second battery, in red, needed 6.5 seconds to reach from 40 % to 4.03%. calculating the slope of the line, both batteries need approximately 2.40 hours (8666.67 seconds) in order to charge to 80%. In addition, the transition of the breakers from being closed to open when the first battery reaches 40.02% and the second reaches 40.03%. Figure 6(b), illustrates that both batteries were charging with 108 volts until the breaker opens and the charging station returns to a harmonic voltage between 138 volts and 167 volts at open circuit. The transformer reduced the the current and increased the voltage every time a car disconneted, indicated it is returning to its set rating because it transitioned from 2 EVs to no load. The same process was simulated, but with an overloaded transformer as seen in Figure 6(c). The results in Figure 6(d), shows that the first battery took 10.43 seconds to charge from 40% to 40.02%, and second battery took 15.33 seconds to charge from 40.03 seconds and shows the transition of breaker 1 and breaker 2 with their respective time. With results from Figure 6(e) the batteries need an approximate of 5.67 hours (20,440 seconds) in order to charge to 80%. Figure 6(f) shows that the overloading has in fact affected the current and voltage output of the transformer.



(a) SOC1 and SOC2 with the state of both breakers with full transformer capacity

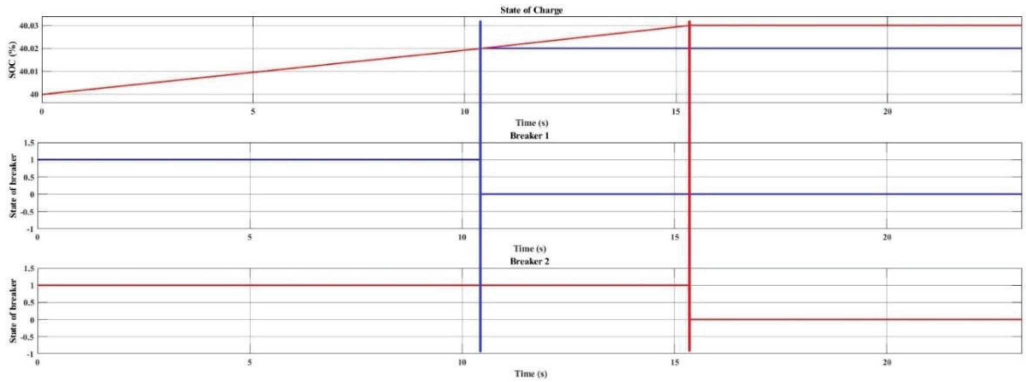


(b) Voltage output of both Charging Stations with full transformer capacity

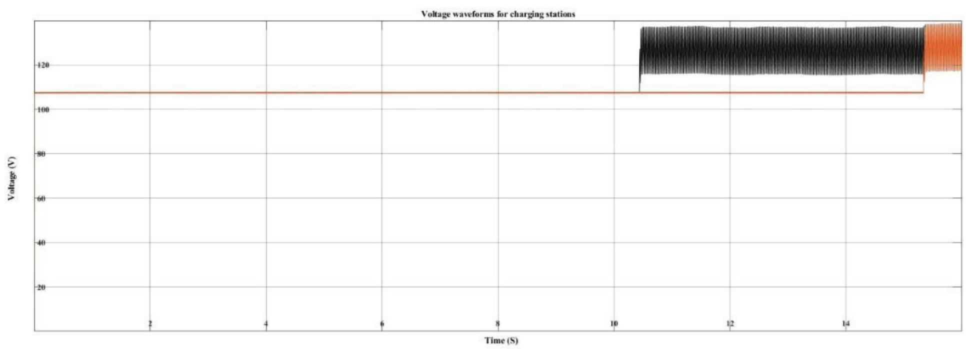


(c) Secondary Current and Voltage of the Transformer with full capacity

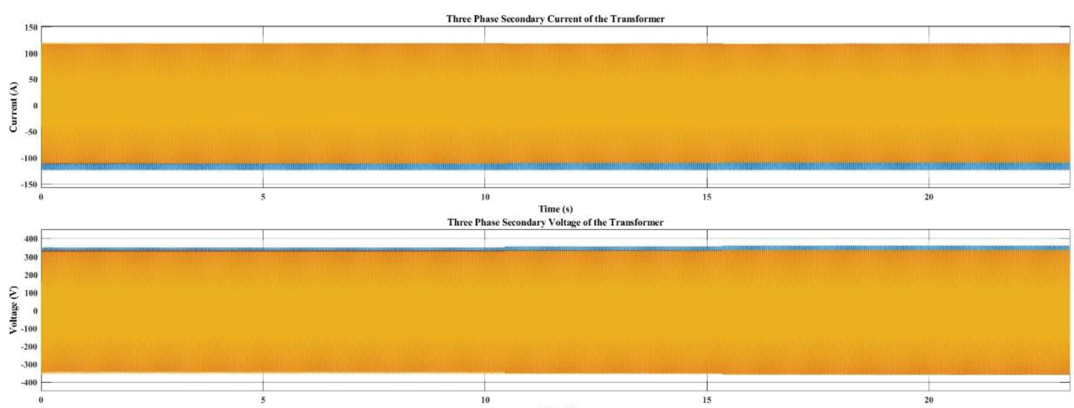
FIGURE 6: Simulation results of the model with a full capacity transformer



(d) SOC1 and SOC2 with the state of both breakers with an overloaded transformer.



(e) Voltage output of both Charging Stations with an overloaded transformer.



(f) Secondary Current and Voltage of the overloaded Transformer.

FIGURE 6 (continued): Simulation results of the model with a full capacity transformer

CONCLUSION

In conclusion, there are two scenarios that are simulated in this model. One simulation having the transformer at full capacity and connected to two EVs, and another scenario is having the transformer overloaded and connected to two EVs. These two scenarios were simulated and analyzed in SIMULINK software, and results concluded that the overloaded transformer took significantly more times than the full capacity transformer, by almost double the time. One way to improve the result is to include a capacitor for the transformer to perform better by having power factor resulting in one.

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