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# EMPOWERING THE GRID: TOWARD THE INTEGRATION OF ELECTRIC VEHICLES AND RENEWABLE ENERGY IN POWER SYSTEMS

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## Abstract

With the transitions of power systems from a traditional structure to a competitive structure, small-scale generators are expected to have a crucial and significant function in the electricity market. Small-scale generators are electric power generation sources that are used scattered in the grid to provide the electricity consumers need and are directly connected to the grid or the consumer's place. This is primarily driven by the move away from traditional power generation sources and regarding RES and EVs. Throughout the globe, utilities, sustainability, and communities all benefit greatly from this transition. Nevertheless, using EVs will have positive and negative effects on the distribution grid. There are many challenges for EVs and the grid when they are connected to the grid. It is essential to assess and analyze the integration of vehicles into the grid that incorporates detailed mechanical and electrical components of EVs and power systems. We examine two important analyses in the power system including RES and PHEV namely, load flow and short circuit calculation. Moreover, this paper defines three cases in load flow analysis and short circuit analysis for 63, 20 KV and explains economic analysis up to the cases, while using DIgSILENT, the analysis is carried out. In conclusion, the findings of this study highlight the significance of PHEV and RES integration in the smart grid, which remains an important task for researchers and engineers.

**Keywords:** PHEV, Renewable energy, Load flow, Short circuit, Power system.

**چکیده:** با انتقال سیستم‌های قدرت از ساختار سنتی به ساختار رقابتی، انتظار می‌رود که ژنراتورهای مقیاس کوچک عملکرد بسیار مهمی در بازار برق داشته باشند. ژنراتورهای مقیاس کوچک منابع تولید برق هستند که به صورت پراکنده در شبکه برای تامین برق مورد نیاز مصرف کنندگان استفاده می‌شوند و به طور مستقیم به شبکه یا محل مصرف‌کننده متصل می‌شوند. این در درجه اول به دلیل دورشدن از منابع تولید برق سنتی و در مورد RES و EV ها است. در سرتاسر جهان، خدمات شهری، محیط زیست و تمام اعضای جامعه از این انتقال سود زیادی می‌برند. با این وجود، استفاده از خودروهای برقی اثرات مثبت و منفی بر شبکه توزیع خواهد داشت. هنگامی که خودروهای برقی به شبکه متصل می‌شوند، چالش‌های زیادی برای شبکه به وجود می‌آورند. ارزیابی و تجزیه و تحلیل ادغام وسایل نقلیه در شبکه‌ای که اجزای مکانیکی و الکتریکی دقیق خودروهای برقی و سیستم‌های قدرت را در بر می‌گیرد، ضروری است. ما دو تحلیل مهم در سیستم قدرت شامل RES و PHEV یعنی محاسبه جریان بار و اتصال کوتاه را بررسی می‌کنیم. علاوه بر این، این مقاله سه حالت را در تحلیل پخش بار و تحلیل اتصال کوتاه برای شبکه ۶۳ و ۲۰ کیلوولت تعریف کرده و تحلیل اقتصادی انجام می‌دهد و اینکار با استفاده از DIgSILENT، انجام می‌شود. نتیجه اینکه یافته‌های این مطالعه اهمیت یکپارچه‌سازی PHEV و RES را در شبکه هوشمند نشان می‌دهد و همچنان اینکار، یک وظیفه مهم برای محققان و مهندسان است.

**کلمات کلیدی:** PHEV، انرژی‌های تجدیدپذیر، پخش بار، اتصال کوتاه، سیستم قدرت.

## 1- Introduction

Arpadzic et al. [1], investigated the PV generators effect on power system network characteristics including the solar energy generation system impacts and some of the most often used variables, like transformer and losses of energy in the RES integration into the grid procedure. Presenting the effects of PEVs on Hungarian distributed system [2]. Employing real data from various grid components, the grid was modeled using the DIGSILENT program. In order to handle regular breakdown assessments in energy systems, the IEC 60909 guideline was recently modified, which include a significant percentage of RES using fully-rated converters, was studied by [3].

Maákowski et al. [4], centered on a model created by DIgSILENT of a photovoltaic (PV) with battery

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energy storage system (BESS) including assessment parameters, like voltage or reactive power (Q), and active power (P). Ref [5] used DIgSILENT to examine the integration on several parameters, including frequency, voltage, and harmonics, and focused on the impact of vehicle-to-grid (V2G) connections at a 33 kV substation situated in Amman. The main goals of [6] was to examine the ways that RES affects fault-ride (FRT) through potential. Some studies examined the integration of RES and EVs on the grid while evaluating several research parameters, including voltage, P, Q, and frequency [1-6]. Azzam et al. [7], discussed the effects of linking Jordan's national grid to large-scale RES plants which include WT, and PV plants. Ref [8], conducted to analyze how the framework voltage pattern is affected by RES. Archana et al. [9], offered a model of a rapid DC charging stations (DCCS) and suggests a way to distribute the stations throughout a distribution system without impacting power stability. An investigation of the effects of PEV charging was presented in Reference [10] using a portion of an actual medium voltage distribution system from Bosnia and Herzegovina as a case study considering three different charging approaches. Fang et al. [11], examined the distribution of EV loads in a specific Hunan region, taking into account the different EV kinds, charging durations, and charging techniques. In order to approximate the load distribution curve, the author used the Monte Carlo random procedure. Using the MATLAB software, Chen et al. [12], explored a fuzzy self-adaptive PID power response approach and created a framework taking EV frequency control into consideration. Cheng et al. [13], examined the best a charging station layout using a particle swarm optimization (PSO). Cheng et al. [14] suggested a way to improve the charging path, traffic networks, CS, and the grid, as well as an examination of the power system's functioning from the standpoint of EV charging needs. Chun-lin et al. [15] concentrated on the effects of widespread EVs utilization on the power supply and mitigating techniques. The power distribution network's ability to operate smoothly may be hampered by the rise in power consumption needed to charge EVs [16]. A pair of models were presented by Mendaza et al. [17]: a V2G and an alkaline electrolyzer. DIgSILENT was used by the author to simulate long-term distribution systems at the two voltage ratings that were taken into consideration: 0.4 kV for the PEV and 20 kV for the electrolyzer grid. Hoseinzadeh et al. [18], applied rate of change of frequency (ROCOF), an active power shortage is determined regardless of grid inertia, form, and number of occurred gradual occurrences following load shedding (LS) phase.

In order to increase the frequency responsiveness and regulation services by implementing energy storage (ES), provide to the grid, especially at high wind penetration, Shim et al. [19], suggested a method for equitably allocating tasks to ESs and power sources. According to Venkateswaran et al. [20], network integration with ESS increased flexibility in the grid and reduced fluctuation brought on by RES. The ecological effects, the land need and related expenses related to installing an ESS, and the renewable purchasing constraint defined in the objective function are the three network efficiency indicators that the author examined. Wirasanti [21], pointed out the operation of V2G in power systems by analyzing frequency regulation, frequency response, and power-sharing between areas. A new approach for PHEV utilization and recharge sensitivity to prices was suggested by Grahn et al. [22]. It is intended to identify charging load profiles according to patterns of driving because of the kind of journey and associated charging requires.

The remaining section of this work is organized accordingly: Section 2 describes PHEV, and RES in power system. Section 3 displays assessment two analysis for corporation of RES, and PHEV. Section 4 includes a brief economic analysis. Section 5 indicates discussion. Section 6 is conclusion.

The following are the study's main highlights:

a. Providing a comprehensive simulation model for integration RES, and PHEV in power system.

b. Conducting dual analyses, like load flow, short circuit calculation.

c. Assessment three cases for load flow analysis in this study.

d. Defining two cases for short circuit calculation.

e. Examination different parameters, like P, Q in each agent like PV, WT, PHEV during load flow analysis.

f. Evaluation different 3-PH, 1-PH, Isc in various location of short circuit in the second analysis.

g. Presentation of a brief review of impacts RES, PHEV in power system.

## A. Motivation

Scholarly opportunities for study abound when RES and PHEVs are integrated into power system assessment. Researchers can investigate the possibility of enhancing grid dependability, and improving security of energy by implementing these revolutionary innovations. Furthermore, examining how renewable energy and PHEVs affect the power grid can yield important information about how to effectively control energy, promote sustainability, and meet carbon reduction targets. The future of clean energy systems is thus shaped by research into the integration of these technologies in power system analysis, which advances our understanding of renewable energy and sustainable transportation so this study bridges the shortcoming depending on to the main highlights.

## 2- RES & PHEV

Because renewable energy resources are ephemeral, there are technical difficulties in grid integration of these systems, particularly at the electrical supply phase. These obstacles include harmonics, voltage imbalances, frequency imbalances, pulse voltage, flickers, and power outages. By resolving peak shaving issues and fostering V2G or G2V operations, EV integration into renewable energy-based grid networks can improve stability and cost effectiveness, especially in microgrids [23]. Ref [24] presented wind and PV affect voltage, with voltage decreasing with wind penetration and increasing with solar penetration. The possible demand brought on by ever more PEV grid integrations raises serious concerns about power system losses as well [25]. Theocharides et al. [26] developed a comprehensive model combining ML and linear regression correction to improve day-ahead solar forecast accuracy, Sun and colleagues [27] presented a theoretical method for improving PV parameters. Petrollese et al. [28] discovered that house PV systems can achieve maximum self-sufficiency rates by employing dependable weather forecast data and optimal energy management procedures. By dispatching the battery system and allocating deferrable loads optimally, they minimized their impact on a grid. Goransson et al. [29] proposed that lowering the cost of grid-integrated PV by using a multi-sectoral strategy that makes use of transient RES in energy-intensive sectors such as transportation, steel, and home heating. With this strategy, system costs could be cut by 8% overall and market prices for electricity may be decreased by 20%. In Larderello, Italy, Prince P.G. Conti installed a grid-connected geothermal power system in 1914. The system produced 250 kW of power through the use of a turbo alternator [30,31]. Independently biomass plants are more cost-effective than hybrid setups, according to a case study conducted in India and Columbia. Grid connection lowers the cost of investment by around 10.5% as opposed to 8.6% for biogas plants [32,33]. For cost-effectiveness, investigators recommend grid-integrated FC to produce hydrogen continuously. Utilizing fuel cell electric vehicles (FCEVs) with vehicle-to-grid (V2G) systems may increase the overall accessibility of hydrogen and fuel cell-based electricity. Reliable strategies for optimization must be implemented for systems to be both economical and productive [34,35]. It has been made demonstrated that using transformer-less inverters for PV increases the effectiveness, lowers prices, and reduces the footprint of PV, making grid connection easier. particularly in households [36]. Ref [37] examined that the widespread deployment of wind power plants affects the stability of voltage in grids, highlighting the necessity of adopting flexible AC transmission systems and efficient line augmentation. Mejía et al. [38], focused on using EVs to help supplying basic frequency management capabilities to maintain the electricity grid. Asadi et al. [39], used a probabilistic method, planning, and placement issue to determine the best way to charge, discharge, and exchange items at a switch site regularly. A powerful reinforcement learning system was employed in [40] to automatically discover the best charging procedures to save battery electricity and duration, enhance customer service, and save expenses. The primary goal of [41] aims to use PSO and evolutionary algorithms to reduce loss of power despite limitations. Ref [42], explored into how a power plant in Saudi Arabia used linear programming techniques in GAMS optimization programs to cut summertime operating expenses in less than a day. In addition to identifying possible structures difficulty and problems including low-fuel cars, [43], looked into integrating thermal energy systems with PV, WT, and electric automobiles. The impact of mirror installation on increasing solar plants radiation and electricity output was explored by Zabihi and his colleagues in [44]. Synthesis inertia, which simulates the inner reactions of both traditional and synthesized converters, may now be studied via modeling on the impact of BESS on steam and WT [45].

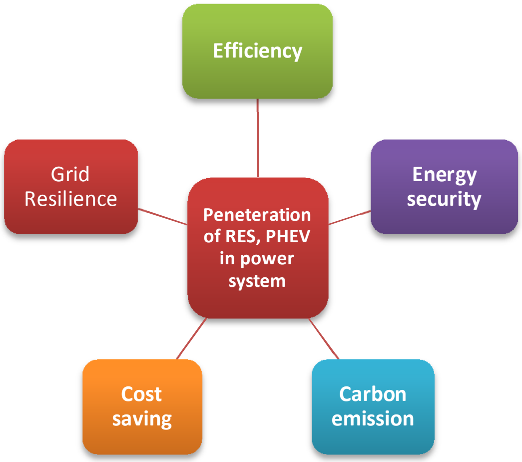


Figure 1.Advantages of integration RES, and PHEV.

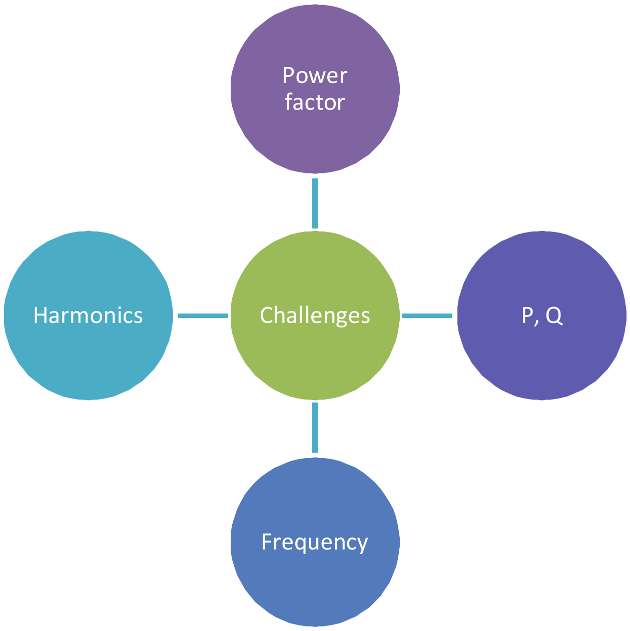


Figure 2. Challenges are imposed by integration RES, and PHEV.

## 3. Analysis of penetration RES, and PHEV

### A. Load flow

The information for transformer in doing analysis up to substation for applying WT and PV plants to the grid is given below in table 1, and 2. Additionally, table 3 describes loads. The following table 4 also provides information of WT. Figure 1, and 2 present advantages of integration RES, and PHEV. Challenges are imposed by integration RES, and PHEV, respectively.

The specifications of distributed generation power plant equipment are presented below. Figure 3 displays the associated electricity system's single-line layout. As shown in the figure below, the studied plan has 2 WT, and PV. These generators include 9 wind units, the type is VESTAS. The practical production capacity of the entire power plant is equal to 6 MW.

Table1.Specification's transformers of substation.

| **Voltage Per Tap** | **Tap changing** | **Vector Group** | **Uk%** | **Voltage Level** | **Nominal power MVA** | **Transformer** |
|---|---|---|---|---|---|---|
| 1.66% | on load | YNd11 | 13.470 | 63/20 | 40 | **T1** |
| 1.66% | on load | YNd11 | 13.470 | 63/20 | 40 | **T1** |

Table2. The 63 kV substation bus has a short circuit level (kA).

| **Single phase** | **3 phase** | **Short circuit bus bar** |
|---|---|---|
| 1.83 | 6.18 | **63kv** |
| 1.34 | 9.65 | **20kv** |

Table 3. Substation load.

| **Maximum load** | | **Voltage level (KV)** |
|---|---|---|
| MVAr | MWAT | |
| 12 | 20 | **20kv** |

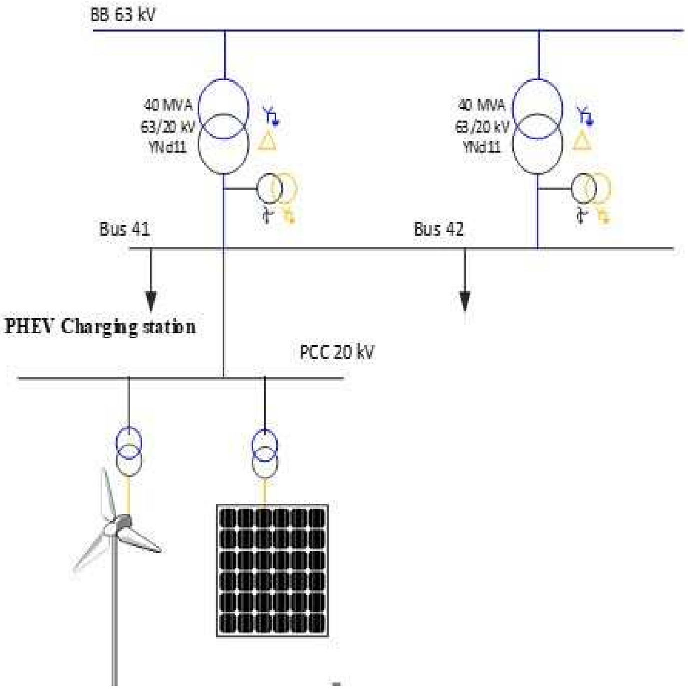


Figure3. A single line diagram showing grid-connected PV and WT.

Table4.Features of WT.

| **Features Of wind turbine** | | | | | | |
|---|---|---|---|---|---|---|
| Number of blades | Height of tower (m) | Nominal voltage (v) | Nominal power (Kw) | Number | Model | **Factory** |
| 3 | 40 | 690 | 660 | 9 | V47 | **VESTAS (Sabaniro)** |

Based on [22] PHEV and vehicle's charging electricity use illustrates in the diagram below. As can be seen from this diagram, the consumption power of electric cars (in the article is given for two million three hundred and eighty thousand people) does not have a specific transient and is a constant load with fluctuations of 25%. Therefore, in DIgSILENT modeling for 500 people and based on the proportional relationship that they use a charging station, the power consumption will be around 3 megawatts. The assumption of 500 people is based on the current situation of Swedish car travel data up to [22]. The schematic of power consumption is indicated in figure 4.

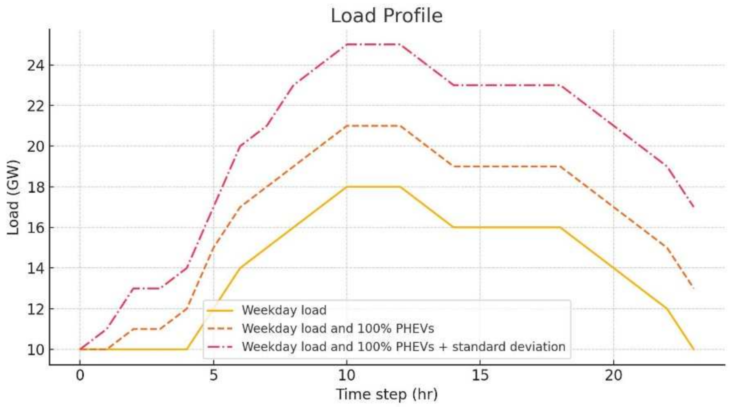


Figure4. Schematic power consumption for 2380000 consumers of Swedish car travel data.

Load flow analyses are essential for integrating distributed generation units into medium-pressure distribution networks. They validate load distribution outcomes within DIgSILENT software, introduce generator connection schemes, and determine optimal reactive power and voltage control. These analyses also identify performance constraints and provide essential details for power quality assessments and protection coordination. The results provide parameters in 1-PH or 3-PH formats to the grid. Load flow calculations in distribution grids involve solving non-linear equations due to the diverse equipment used and the necessity for prompt and accurate decision-making during operations. Software is indispensable for conducting load flow studies and other system analyses efficiently. This study focuses on load flow analyses using DIgSILENT software in three scenarios: without renewable power plants and PHEVs, with PHEVs but no RES, and with RES. The analysis commences with implementing the Newton-Raphson load flow algorithm without considering Distributed Generation (DG) plants. Peak load simulations are discussed for each scenario, with Table 5 presenting the corresponding results for cases 1 and 3.

## Case1: Simple power grid without RES and PHEV

## Case2: With the presence of renewable power plants and PHEV

As it is known, the production amount of the power plant causes a part of the consumption load to be supplied locally. From the point of view of voltage, the minimum voltage level at the level of 20 kV has reached 0.978, which is important compared to the state without DG, which was 0.976. Considering the nature of its power production, the solar power plant participates in the production of power and does not have a special role in the production of power. In the case of the wind power plant, in addition to injecting active power, reactive power is also injected into the network, which caused the reactive power drawn from the network to decrease, and from 13.8 in the absence of the power plant Renewable to reach 12.5. In this part, the summary of the results of the studies that were explained in the previous paragraphs is briefly stated. Table 5 indicates results according to case1, and case 3. For more simplicity, the important parts of the results are given in the table 6 below so that they can be compared.

According to what was stated in this section of this study regarding load flow calculations, the voltage of all buses in the state of generator connection did not exceed the allowed value of 1 ± 5% and the voltage of all substation components in these studies was within the allowed range of operation. When running at the full load, a scattered-producing power plant raises voltage to a level of 20 kV.

Table 5.Summary of load flow calculation results in case one and three.

| Details of load flow | Wind generation MW | PV generation MW | Wind generation MW | Wind generation MVAr | Grid generation MVAr | Grid generation MVAr | PHEV MW | PHEV MVAr | Conclusion in voltage | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 20kv PCC | | 20kv substation | 63 kv substation |
| | | | | | | | | | Wind turbine | PV | | |
| Without RES and PHEV | - | - | 20.1 | - | - | 13.8 | - | - | - | - | 0.976 | 1 |
| With RES and PHEV | 5.9 | 6 | 11.2 | 3.2 | ۰ | 12.5 | 3.1 | 2.5 | 0.978 | 0.984 | 0.978 | 1 |

## Case 3: Grid with PHEV and without RES

The study of grid load flow with the considered scenario is shown in Figure 6. The full results of this load flow are given Table 7 also shows the comprehensive information of the grid with PHEV and without the presence of the installed capacity of renewable resources. According to the results, it can be seen that P injection to the substation has changed from 12 to 42 MW, as well as grid losses from 0.19 to 0.27 MW.

In the second scenario, due to the absence of distributed generation power plants, all the power demand of active load and EVs is provided from the grid. According to the table7, the maximum amount of P received from the grid occurs in the second case. On the other hand, comparing all scenarios with each other, the lowest amount of receiving Q from the grid occurs in the third case, which is due to the installed capacity of WT and injecting Q into the grid. The bus voltage of 63 kilos is always equal to 1 Per- unit in all scenarios, due to the direct connection to the external grid. On the other hand, the 20 kV busbar (output feeder) in the first and second scenarios is equal to 0.976 and in the third scenario, due to the injection of Q into the grid, it is equal to 0.978, which is due to the direct relationship between the Q and the grid voltage has improved. The voltages are always within the permissible range defined by the standard for the connection of renewable power plants.

Table 6. Results of load flow.

| Load flow calculation | Wind turbine MW | PV generation MW | Grid generation MW | Wind turbine MVAr | PV generation MVAr | Grid generation MVAr | PHEV (MW) | PHEV MVAr | Voltage conclusion | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 20kv | | 20kv substation | 63 kv substation |
| | | | | | | | | | Wind turbine | PV | | |
| Without PHEV and RES | - | - | 20.1 | - | - | 13.8 | - | - | - | - | 0.976 | 1 |
| With PHEV and without RES | - | - | 42.54 | - | - | 13.05 | 10.02 | 5 | - | - | 0.976 | 1 |
| With PHEV and RES | 5.9 | 6 | 11.2 | 3.2 | ۰ | 12.5 | 3.1 | 2.5 | 0.978 | 0.984 | 0.978 | 1 |

### A. Short circuit analysis

This segment examines short circuit studies of the grid when incorporating distributed generation units (DG) into the medium distribution network. It evaluates short-circuit current and its adverse impacts on the grid, using software to conduct calculations. The integration of DG significantly influences the operation, protection, and control of distribution and transmission systems. Conducting short-circuit studies in distribution networks with scattered production sources is crucial due to the potential for 80% of the short-circuit current flowing through power switches. $\boldsymbol{I_b}$ component or the interrupting current by the breaker is investigated. The value of $\boldsymbol{Ib}$ is rms value of $\boldsymbol{Isc}$ at the moment the breaker opens (generally 20 to 300 milliseconds after the fault starts). Therefore, the breaker must stop this current. As a result, the criteria for selecting power switches should be based on $\boldsymbol{I_b}$value. In this study, $\boldsymbol{Isc}$ is determined using the IEC60909. Additionally, a total short circuit time of 1 second is considered based on a minimum relay operation time of 0.1 second, with fault resistance assumed to be zero. Short circuit current calculations are carried out for the 63, 20 kV substation, and scattered generation power plant buses. The locations for calculating fault currents are specified. Various scenarios for fault current calculations are explored, including situations with no connection of DG and with DG connected. The analysis presents results for short circuit faults on the 63 kV bus, followed by an examination of results concerning the 20 and 11 kV buses.

## Case1: 63 kV substation bus

This section presents the findings from the 3-PH and 1-PH short circuit on the 63 kV busbar both before and after the distributed generation power plant was connected to the substation. Figure 5 illustrates the scheme of single line diagram for analysis of short circuit in this study.

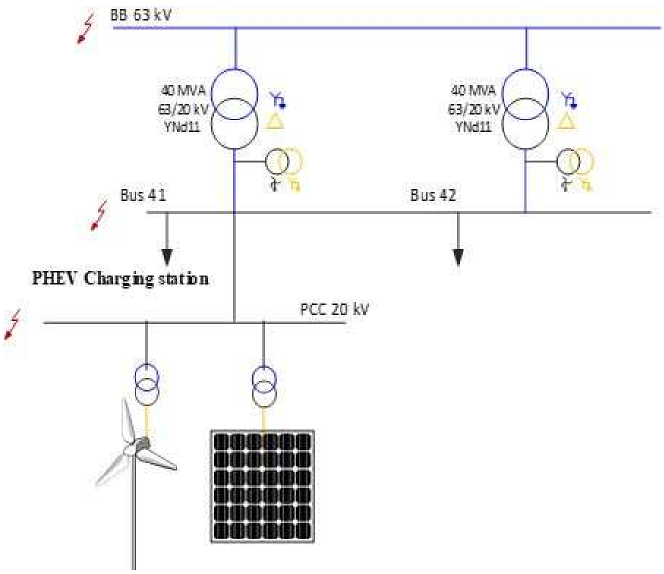


Figure 5. Layout of the second analysis.

## Case2. 20 kilovolts substation

This section evaluates the connection between single phase and three phase at 20 kV before and after distribution generation connection on substation, revealing short circuit calculations. $Isc$ remains relatively stable concerning the short-circuit level of the 63 kV substation. The $Isc$ on the buses is below the circuit breakers' maximum rating at the 63 and 20 kV substations. The results show the highest possible current via the circuit breaker and the amount of $Isc$ for the power plant's authorized breakers.

Table 7. Result of short circuit studies.

| After connecting DG | | Before connecting D | | |
|---|---|---|---|---|
| Imax-sc.1-phase (KA) | Imax-sc.3-phase (KA) | Imax-sc.1-phase (KA) | Imax-sc.3-phase (KA) | Location of short-circuit |
| 1.828 | 6.141 | 1.835 | 6.183 | 63kv substation |
| 1.365 | 9.659 | 1.39 | 9.649 | 20kv substation |
| 0.182 | - | - | - | Output wind farm plant |
| 1.11 | - | - | - | Output solar plant |

## 4. Economic analysis

According to our work, in the first scenario (without a RES and EV), the amount of power received is equal to 20.1 MW and 13.8 MVAr. This means that if this demand is entirely met by traditional power plants, it will cause environmental harm and pose dangerous challenges. On the other hand, in the second scenario, if only electric cars without RES capacities are used, this will indirectly lead to environmental crises, with the amount of power received from the grid equaling 42.54 megawatts and 13.05 MVAr, exacerbating environmental challenges. In the third scenario, the simultaneous presence of RES and EVs in the distribution grid will cause a decrease in the amount of P received from the grid, as well as a help in reducing the consumption of fossil fuels and environmental crises. At the outset, it is accurate that the expenses associated with constructing RE facilities or acquiring EVs may be substantial. However, with governmental backing policies and returns on investment for private sector stakeholders, these initiatives are expected to become profitable in the long term.

## 5. Discussion

In this paper, we consider the incorporation of PHEV and renewable energy distributed generation in smart grids. We utilize DIgSILENT software to assess load flow calculation and short circuits in different scenarios, namely with DGs and without it. The first scenario involves calculating load flow in three cases: the simple grid without PHEV and RES, the grid with PHEV without RES, and the grid with PHEV and RES. Additionally, we examine short-circuit calculations for 63 and 20 kV substations. Based on the load flow results shown in Table 6 for cases 1 and 3, the power plant's production contributes to supplying a portion of the local consumption load. The minimum voltage level at the 20 kV level has increased to 0.978, which is significant compared to the state without DG, which was 0.976. As for the wind power plant, it injects both P and Q into the network, leading to a decrease in the Q drawn from the network, from 13.8 in the absence of renewable power plants to 12.5.

The provided table appears to compare two different scenarios involving power generation, consumption, and the impact of PHEVs and PV systems. It includes various parameters for what seems to be an electrical grid or a power distribution model. In the first row (without PHEV), the power grid has a PCC voltage conclusion of 0.976, with a significant contribution from wind turbine generation (13.8 MW). There is also substantial grid general compensation (20.1 MVAr) noted, but no contributions from PHEVs, wind generation, or PV generation are recorded. This scenario has less complexity and fewer power generation sources. In the second row (with PHEV), the PCC voltage conclusion is slightly higher at 0.978, and there is a diverse mix of power sources contributing to the grid. This includes wind turbine generation at a smaller scale (25 MW) and additional contributions from PHEVs (0.978 MW), wind generation (6 MW), and PV generation (5.9 MW).

There are also multiple entries for grid general compensation, suggesting a more complex system of voltage and reactive power support, with values ranging from 3.1 to 11.2 MVAr. Comparing the two rows, we can see the presence of PHEVs and other RES, like WT and PV, indicates a slight improvement in the PCC voltage conclusion and a more diversified power generation and compensation strategy. The consideration of PHEVs seems to contribute to a more robust and possibly more sustainable grid infrastructure by integrating multiple small-scale generation options and managing power flow more effectively. It also demonstrates that the grid is capable of handling additional complexity introduced by PHEVs, without significant negative impact on the voltage levels at PCC.

According to second scenario, all power demand from active load and PHEV is supplied from the network due to the absence of DGs. The maximum amount of P received from the grid occurs in the second case. Additionally, when comparing all scenarios, the lowest amount of Q received from the grid occurs in the third case. This is attributed to the installed capacity of WT and the injection of Q into the network.

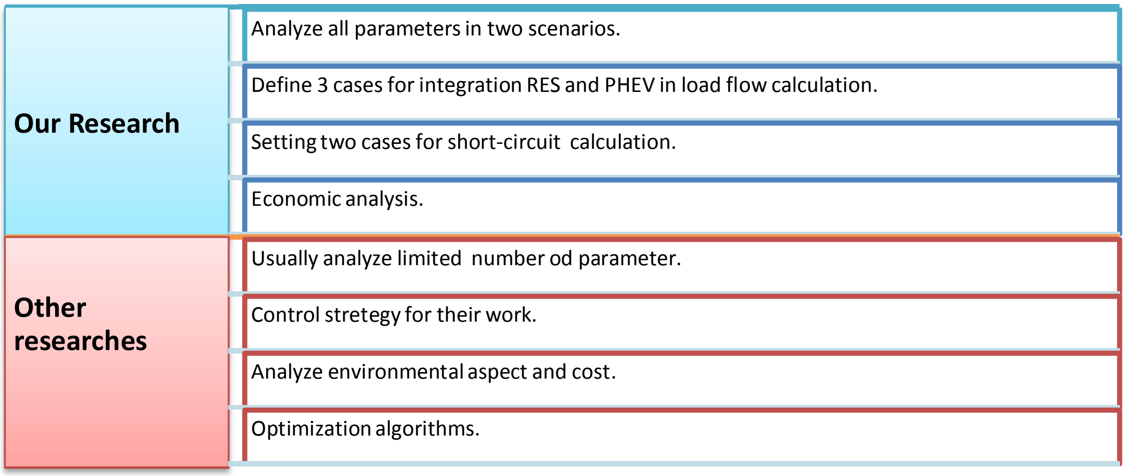
The 63 KV bus remains consistently at 1 Per-unit in all scenarios, owing to its direct connection to the upstream grid (External Grid). On the other hand, the 20 kV busbar (output feeder) is 0.976 in the first and second scenarios, and 0.978 in the third scenario due to the injection of Q into the grid. This improvement is a result of the direct connection between reactive power and the grid voltage. Importantly, the voltages always remain within the permissible range defined by the standard for the connection of renewable power plants.

Table 7, describing the results of short-circuit calculation, appears to be a comparison of electrical parameters before and after connecting a distributed generator (DG), potentially in power distribution networks. The locations include a 63kV substation and a 20kV substation for solar plant and wind farm outputs.

- Connecting the DG seems to have a variable effect on the short-circuit currents:
- At the 63kV substation, the 1-PH maximum short-circuits current decreases, but the 3-PH maximum $\boldsymbol{Isc}$ remains unchanged after connecting the DG.
- At the 20kV substation, there is a dramatic decrease in the single-phase maximum s $\boldsymbol{Isc}$ after connecting the DG, while the 3-PH maximum $\boldsymbol{Isc}$ remains unchanged.
- The wind farm plant, only the single-phase maximum short-circuits current after connecting the DG is shown, and it is relatively low compared to the substations. This could be indicative of the wind farm's smaller scale or different network characteristics.

From an engineering perspective, these changes in $\boldsymbol{Isc}$ can have significant consequences for the electrical grid's functioning, layout, and security. Protection systems and equipment must be correctly rated to handle these currents, ensuring safe and reliable operation.

Furthermore, the future extension of the flexibility model will incorporate the charging station, which will play a pivotal role in our work. This extension will enable the analysis of our power system, encompassing electric vehicles, the DGs, and CSs. Engineers can apply optimization calculations to the future system, considering various parameters such as electricity cost, carbon footprint, and charging prices. The model might be improved by including a signal for high versus low emission levels alongside to the recharging costs. The model can be expanded in further studies to include V2G and power grid models.



| | |
|---|---|
| **Our Research** | Analyze all parameters in two scenarios. |
| | Define 3 cases for integration RES and PHEV in load flow calculation. |
| | Setting two cases for short-circuit calculation. |
| | Economic analysis. |
| **Other researches** | Usually analyze limited number od parameter. |
| | Control stretegy for their work. |
| | Analyze environmental aspect and cost. |
| | Optimization algorithms. |

Figure 6. Comparison between our research and previous researches in this field.

## 6. Conclusion

This paper considers incorporation of PHEVs and renewable distributed generation into smart grids. It uses DIgSILENT software to analyze scenarios with and without distributed generation in a grid model. We define three scenarios for load flow implemented namely; simple grid, with PHEV and without RES, with PHEV and RES. Moreover, two scenarios were defined for short circuits in two substation buses 20kv and 63kv. Short circuit and load flow evaluations are carried out. Results indicate that adding PHEVs, RES like wind and solar PV leads to improved voltage levels and more diverse power sources. Integrating these resources provides a more robust grid infrastructure by effectively managing power flows. While short circuit currents are impacted variably by distributed generation connections, protection systems must be rated accordingly to ensure safe grid operations. For future study can be added EVCSs, and considering the price, while this addition will allow for analysis of the power system incorporating EVs, distribution networks, and charging infrastructure. Optimization calculations can then be applied to the expanded system taking into account factors like electricity prices, carbon emissions, and charging fees. Incorporating signals to distinguish high and low emission times in addition to charging prices could improve the model.

Moving forward, the model could be further built upon to integrate physical grid models and vehicle-to-grid technologies that allow EVs to supply power back to the grid.

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