Executive Summary

In line with its vision to be a world-class company, Meralco has been actively taking steps toward distribution grid modernization by integrating renewable energy (RE) into the system. This is a major boost towards the goal of the Department of Energy (DOE) to triple the capacity of RE in the Philippines between 2010 and 2030 to 15,304 MW as outlined in the National Renewable Energy Program (NREP). However, disruptive technologies such as those present in hybrid renewable energy systems pose various challenges to the secondary distribution network especially since the Energy Regulatory Commission (ERC) had released the resolution allowing all qualified end-users to install Embedded Generators (EG) and participate in the net-metering program.

Not only does the installation of EG have significant impact on the distribution system's power quality, the process of applying for net-metering services in itself can be costly, time-consuming and labor-intensive both for the customer and the distribution utility (DU). There are 6 steps in applying for net-metering services from applying for interconnection to energization. In the worst-case scenario, the whole process can take up to 155 days (not including the days devoted for the testing and commissioning of the installed facilities to be witnessed by the DU) to complete and the fees for the necessary Distribution Impact Study (DIS) and Distribution Asset Study (DAS) amount to a total of approximately Php 17,700. In order to evaluate the effects of hybrid systems on secondary distribution networks and thereby improve the overall net-metering application process, DCSAM extended its study to hybrid RE systems (with emphasis

on solar, wind and biomass) by analyzing its impact and suggesting penetration limits for a specific set of EG.

The study used a deterministic approach by collecting data from an actual system representing the worst-case scenario for selected secondary distribution networks (SDN) then simulating the effect of injecting different types and combinations of embedded generators on the grid. In order to create a practical hybrid system simulator, a set of codes were programmed to perform load flow given load and line connectivity as input and yielding system loss, branch ampere loading and voltage level as output.

The study was able to determine the maximum allowable power generation for a single-installation of EG for various types of RE system and secondary feed.

Other notable findings produced by the study is the existence of a range in which system loss decreases with increasing EG capacity before it begins increasing infinitely and the range of EG capacity that results in a decrease in branch ampere loading, the conclusion that the worst point of injection for any EG is the load farthest from the distribution transformer and a comparison which shows that distributed generation allows for capacity much more than that of aggregated generation. In addition, the simulator was programmed with the capability to simulate different types of load profile for any model of EG (DC, synchronous and asynchronous) hence, it is already suitable for use in the industry.

Using the tools and analyses that this study had yielded, the amount of manhours and labor necessary for future distribution impact and asset studies had been greatly reduced. These results may now be used in order to implement policies and set standards that would make the net-metering application faster, more efficient and less costly. As a consequence of this study, Meralco has ensured that the system maintains high-quality while staying safe, reliable and more environmental - making its secondary distribution networks future proof.

Introduction

Renewable energy (RE) is energy generated from natural resources such as sunlight, wind, biomass, and many other. The revolutionary breakthrough on the invention of the generators that are used to harness energy from our natural resources paved way to the introduction of even more efficient solar panels, wind mills, and other devices. Solar Photovoltaic energy generation from sunlight is the most famous kind of renewable energy generation. According to the Philippine Power Situation Report, solar energy comprises 3.57% of the total RE generation in the Philippines as of 2016. Wind energy generation, on the other hand, comprises the 1.99% of RE generation, while biomass comprises the 1.09 percentage. This RE generation, when connected to an electrical distribution network, is considered as embedded generation.

The discovery of multiple types of RE sources triggered the introduction of penetration of two or more types of embedded generators (EG) in a single residential electric system. The combination of two or more modes of electricity generation such as solar photovoltaic and wind turbines in an electric system is known as hybrid system. This study is focused on the residential-level hybrid system with combination of three renewable energy generators--solar panels, wind turbines, and biomass energy generators.

In contrary to most people's misconception, hybrid system does not necessarily mean that two or more EG's are installed in the same load. Any system that utilizes two or more EG's is categorized as hybrid system, no matter where every EG is installed within the electric system. (3)

The Philippines' economic and environmental concerns are important factors to consider when it comes to generating energy. The country's response to this concern lead to the increase in the demand for reliable carbon-free methods to generate electricity, like generating energy using solar panels. Solar panel installations in the Philippines is rising and various studies have been conducted to study the impact on the distribution system parameters when there is solar energy penetration in the electric system. Studies shows that too much power coming from embedded solar energy generation causes increase in voltage and current, exceeding their nominal values.

The rise of hybrid system offers threat to distribution utilities for no enough study has been conducted to determine how hybrid systems affect the distribution parameters in low voltage. Unlike the sole installation of solar panels, hybrid system has more than one value of power factors to consider because every EG has its own power factor. Solar energy generation has a power factor of 1.0, wind energy generation has a power factor of 0.95, and biomass energy generation has a power factor of 0.8. If all these types of EG's are present in a system, all of their power factors should be taken into consideration.

The concern of this study is to determine the effects of hybrid system to distribution system parameters. These parameters are voltage, ampere loading, and the system loss. MERALCO, being a distributor of electrical power, must adhere to the policies set by the regulatory commissions regarding the proper compliance on the distribution system parameters. Therefore, all of its actions regarding electric distribution must not result to violation of any law.

One of the distribution systems parameters is the voltage. Here in the Philippines, the secondary distribution systems' nominal voltage is 240 volts. As mandated by the Energy Regulatory Board in the Resolution No. 95-21, Section 16a, all electric utility have to maintain the voltage variation of 10% above or below the nominal voltage adopted for service rendered under a power contract; and 5% above or below nominal voltage adopted for service rendered under a lighting contract. Any value beyond those is considered violation. In this study, the chosen voltage variation is plus or minus 5% of the nominal voltage because it is the safest for all types of contract.

Another parameter is the branch ampere loading. In this study, the line model used for the secondary feed is taken from actual Meralco standards for overhead secondary and service lines. The secondary line (SL) has a current carrying capacity of 215 A and the service drop (SD) has a current carrying capacity of 70 A. The maximum branch ampere loading of SL and SD must not exceed 80% of their current carrying capacity.

The third and last parameter is the system loss. Though there is no law that sets minimum or maximum system loss, it must be kept minimum to avoid energy losses and line losses, thus avoiding too much cost for the company.

The behavior of the three system parameters are to be observed all at the same time when the EG's penetrate the distribution system. A wide range of values of the total generated power from 0.5 kW to 30 kW was injected to the secondary feed. The smallest value of the injected generated power in which either of the voltage or branch ampere loading will be violated first will be the hosting capacity of the system.

Three types of secondary feeders are used in this study in order to examine the effects of hybrid system on the distribution system parameters in different feed profiles. These are the One-way, Two-way, and the Three-way secondary feed. The profile of the One-way secondary feed we used has only one main branch and has 18 nodes, two main branches and 25 nodes for the Two-way, and three main branches and 26 nodes for the Three-way.

All of the computations are done through simulation using MATLAB. With the existing secondary feed profile, standards, and formulas, the researchers created their own programming codes to simulate all the possible scenarios with different combinations of secondary feed and locations of the EG's.

Basically, this study is focused on determining the maximum generated power a system could accommodate before it violates the limitations of the distribution system parameters. The maximum allowable generated power of any hybrid system before any violation in voltage or branch ampere loading occurs is the hosting capacity.

SIGNIFICANCE OF THE STUDY

Parallel to the main goal of MERALCO, which is to become a world class distributor of power, this study is ahead in determining the effects of hybrid system to distribution parameters. The untouched topic has very limited studies and thus must be further delved on in order to ready MERALCO to possible changes when hybrid systems are injected to the system.

Usually, before a customer is granted the permission to install a renewable energy to his or her house, a consultation must first be done whether or not the renewable energy to be installed would cause detrimental effect to the distribution system. Through this study, the consultation process can be removed by means of standardization. This study proposes the hosting capacity or the maximum rating of renewable energy to be installed.

The main objective of this study is to identify the effects of the hybrid system to the distribution parameters which are the voltage and branch ampere.

SCOPE AND LIMITATIONS

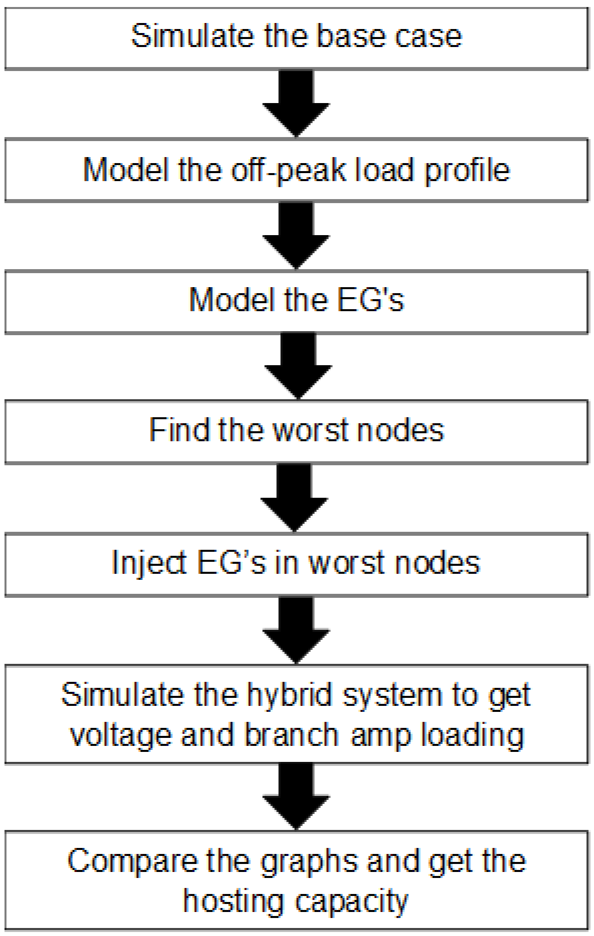
This study focuses on sensitivity analysis and other power quality issues (making sure that the network is compliant with ERC's voltage level requirement). It does not cover stability (determining if the distribution network becomes more stable with more hybrid system installations) and reliability (determining if reliability factors - SAIFI, SAIDI and others improve with more EG installed in the network).

In addition, out of all the system requirements set by the ERC (limitation of DC injection, flicker sensitivity, harmonics and power factor), only the voltage level is under the distribution utility's control - the rest are dependent on the end-user. It would be ultimately beneficial for the utility to study which machine specifications would best meet the requirements set by the ERC. This would give staff engineers the capability to recommend the best type of machines for specific secondary distribution network to end-users in the future.

Moreover, this study investigates the overall condition of the distribution system at steady-state. In other words, it takes a *snapshot* of the system's behavior at one point in time. We tested multiple cases by varying the output power generation of the installed embedded generator and treating the values as discrete (points) rather than continuous (curve, as in Transient Analysis). Hence, we weren't able to capture the effect of sudden drastic changes in the output generation, i.e. short-term fluctuations of solar and wind energy (e.g. when solar power generation ramps up and down abruptly due to cloudiness and overshadowing or when there's a sudden gust of wind). This instantaneous changes in the behavior of renewable energy systems is considered to be one of its major disadvantages compared to traditional energy sources. In order to extend this study for transient analysis, more data (including typical per-hour output curves for different types of embedded generators used in a Philippine setting) would be required than what is available at the moment.

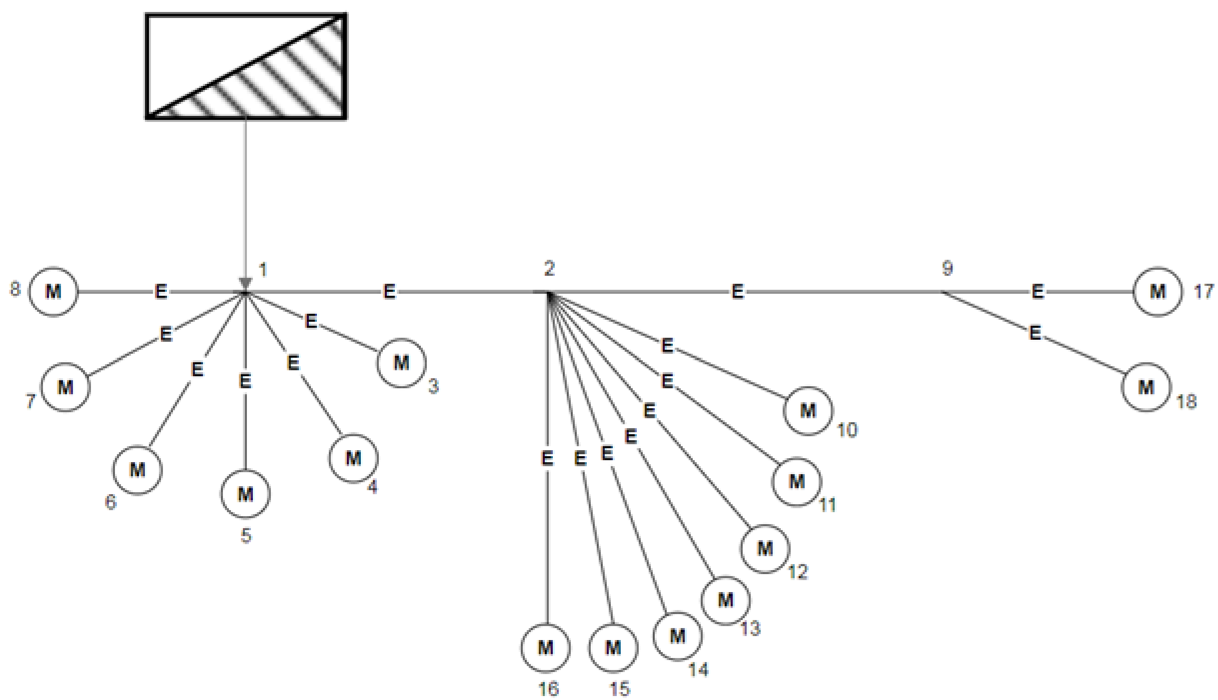
On the whole, a standardized method for SDN analysis has yet to be set in the renewable energy industry. As a result, most studies use different methods using various software and applications available for both specific (practical) and general (theoretical) test cases. It is worth noting that due to time and budgetary constraints, our team decided to use the software that is free, available and one that has a programming language we are familiar with - hence, the use of MatLab and Octave-Online (for the online *shared workspace* feature). However, engineers in the distribution system industry typically use other software such as OpenDSS, ANASYS, ETAP, DIgSILENT, etc. These applications are not free and use different programming languages for its scripting. It is worth noting that the applications aforementioned, unlike the software used for this study, already include built-in models (for regular traditional generators and renewable energy sources) and power system analysis tools (Gauss-Seidel, Newton-Raphson, etc). In the future, this could save the engineer a huge amount of time as one would just need to input relevant data and select the type of power system analysis instead of having to code it manually similar to what was done for this study. It would be best to invest in a reliable, fast, accurate, comprehensive and easy-to-use software for power system simulation as results from these simulators can result to huge savings in preventive maintenance, operations, distribution planning and repair.

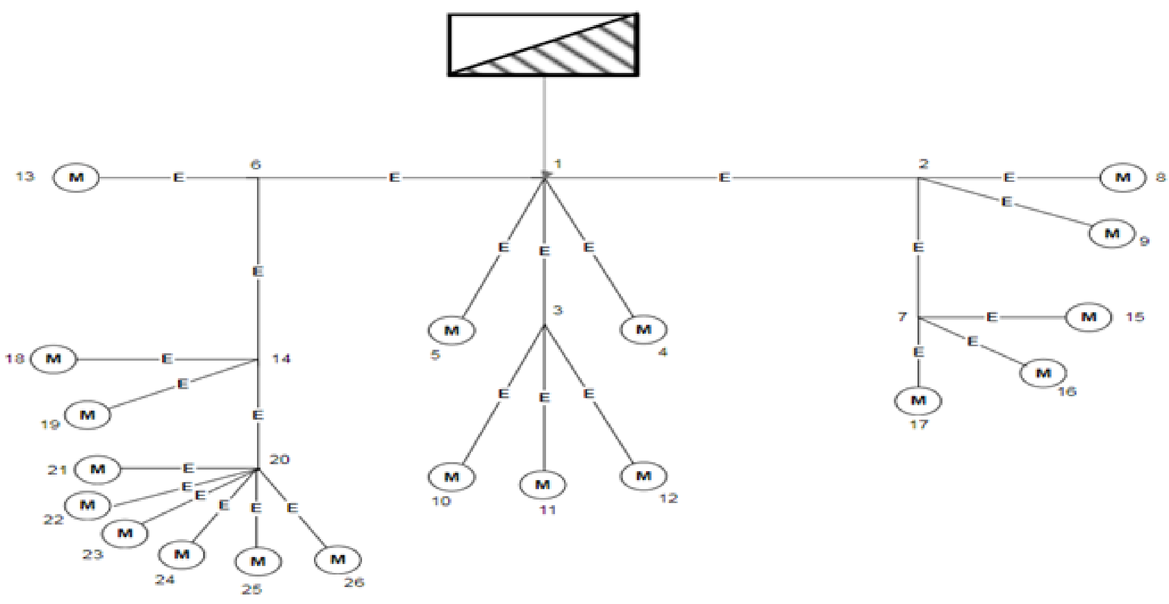
METHODOLOGY



This part contains the methods, the models and the systems used in the simulation of data. Using a MATLAB software, a multi-paradigm numerical computing environment, the group developed a code where the simulation was completed. In order to know the effects of a hybrid system installed in a house, a simulation in MATLAB is done wherein each customer or house is installed with a hybrid system. The group used the load profile of a consumer to make the simulation more realistic. The load profile data was obtained from Meralco. It contains the power consumption of each customer and the distance of the house from the transformer.

There are many ways to model a system. It can be using the generator's efficiency, coefficient performance, turbine types etc. For simplification, the model used in this study is based on the renewable energy system's power factor. For a PV system, the power factor is unity. The wind renewable energy on the other hand uses 0.95 and the biomass generator uses 0.8 lagging power factor. According to Opila et.al.(2010), wind turbine generators are capable of operating over a power factor of 0.95 lagging to 0.95 leading. Biomass generators, on the other hand, usually operate at 0.8 lagging power factor.





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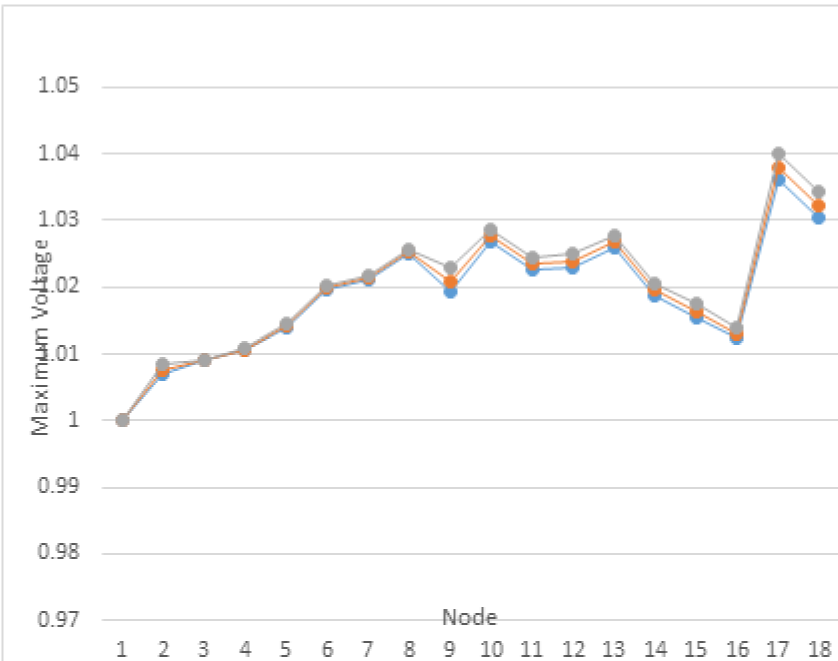
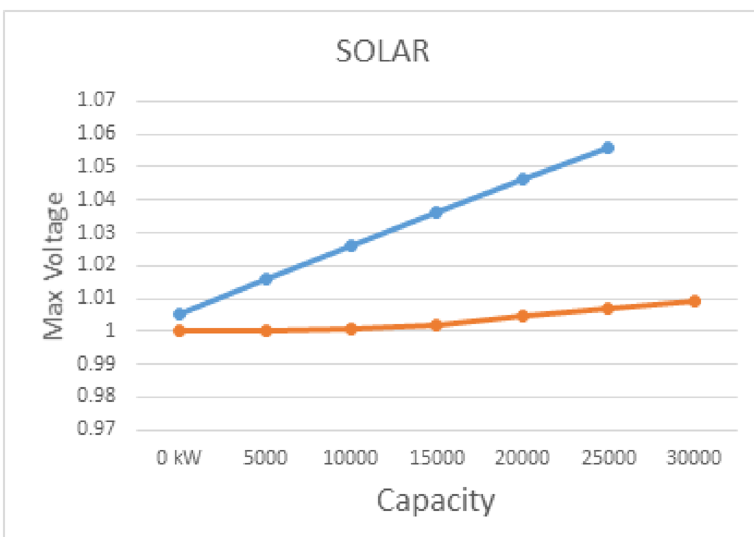
The figure above shows the types of secondary feed. The types can easily be distinguished by counting the number of branches from the transformer. The “M” represents the houses connected to the transformer. Any of the houses can install a system of renewable energy. But for simplification, the worse house for the injection of RE system was considered. The location of the house is referred to as a node. In order to find the worse house location where the hybrid system will be installed, a simulation was conducted wherein each houses are installed with RE one by one. In determining the worse node, two parameters are considered, the one with the highest voltage and the one with the highest system loss.

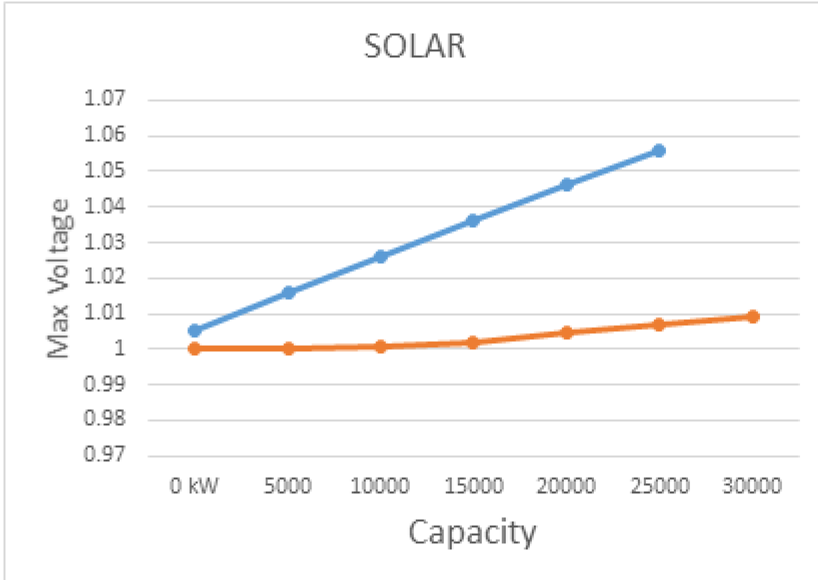


The graph above shows the maximum voltage emerged when a renewable energy is installed in a house numbered one to eighteen. Three series of lines represents the kind of renewable energy installed. The highest maximum voltage occurred in node 17 where it hit 1.04. The node also has the highest remarkable system loss which hit 2.3 kW. This node is the worse node for 1 way secondary feed. The worse node for 2 way and 3 way are 23 and 15 respectively. This was obtained by determining the highest voltage and system loss of each kind of secondary feed.

It can be noticed that the worse node is located farthest from the transformer for 1 way, 2 way and 3 way secondary feed. The distances of each node to the transformer is as follows: Node 17 for 1 way is 96.4 m away, node 23 for 2 way is 117 m away and node 15 for 3 way is 111 m away. It can be deduced that the worse node is location dependent and occurs at the farthest node from the distribution transformer.

Having the assumption that any customer can install renewable energy system in their respective house, it is very practical to know the difference of distributing the renewable energy system to each house compared to injecting the renewable energy system to only one node or one house. A separate simulation was made in order to assess the difference between the two. Two scenarios are compared during this simulation. First is the installation of each aggregated RE system to the worse node and the second is the installation of RE system to all of the nodes for 1 way, 2 way and 3 way feed.





The behavior of Solar RE system to the other two system is very similar. As the input power generated or capacity increases, the loading and the maximum voltage also increases. But there is a significant difference when the aggregate is compared to the distributed RE system. In the graph against maximum voltage and capacity, the voltage is violated when the capacity reached 25 kW. Contrarily, in the simulation where the RE system is distributed to all nodes, the maximum voltage does not reach the allowable limit although it passed the 25 kW mark. The same is true with the 2 way and 3 way system.

To wrap up the comparison, when the RE system is distributed to all the nodes, the voltage and the loading decreases its slope, meaning the capacity before which a violation occur is much higher compared to the capacity of the aggregated RE system. Hence, the distributed RE system can't be considered as the worse type of scenario when dealing with the injection of RE system in the grid.

Another simulation was made wherein the hybrid system is distributed among three worse nodes. The results obtained are parallel to the simulation wherein only one node is injected with a hybrid system. Both shows linear curve of system loss, maximum voltage and loading.

	Renewable Energy System	1st worse node	2nd worse node	3rd worse node
1 Way	Solar	17	18	10
	Wind	17	18	10
	Biomass	17	18	10
2 Way	Solar	23	22	20
	Wind	23	22	20
	Biomass	23	22	20
3 Way	Solar	15	23	9
	Wind	15	23	9
	Biomass	15	23	9

The table above summarizes the worse nodes obtained from the simulation. The data was obtained by determining the highest voltage and loading occurred for each type of secondary feed. Obtaining the worse nodes for each type, a simulation was made wherein the 3 RE is distributed among the 3 nodes. As stated in the introduction, any system can be called a hybrid system if two or more RE are present in a network. There are a total of 24 combinations for a hybrid system that can be installed in the 3 nodes. The researchers wishes to find out the worse combination of RE by looking at the maximum voltage and the loading for each combination of RE.

The worse combination of RE system for 1 way occurred when the biomass generator is injected at node 17 which is the worse node, wind generator at node 18 which is the second to the worse node for 1 way and the solar generator injected at node 10. For 2 way kind of secondary feed, the worse combination occurred when the biomass generator is injected at node 23, the wind generator injected at node 22 and the solar generator injected at node 20. Lastly, for the 3 way, the biomass generator is injected at node 15, the solar injected at node 23 and the wind generator injected in node 9.

A system becomes ideal as its power factor draw closer to one. The power factor is the displacement of the supply voltage to the current of the load. When the power factor is one or unity, all the energy supplied by the source is consumed by the load alone. Therefore there is a minimum loss in the system. Harmonics, which can cause damage in cabling equipment within its network, will be absent. Since the power factor of solar PV generator is unity, it will not produce the worse combination if solar PVs are injected at the first worse node. It is to be injected at the least node on the list. The biomass generator has 0.8 pf, far from the unity power factor, therefore, the worse combination will be obtained if the biomass generator is injected at the first worse node and the wind generator, having a power factor of 0.95 must be injected at the second to the worse node.

Focusing on the worse combination, the researchers increase the input generated voltage of the hybrid system for which it will violate the set 5% plus or minus the voltage or the loading at 100.

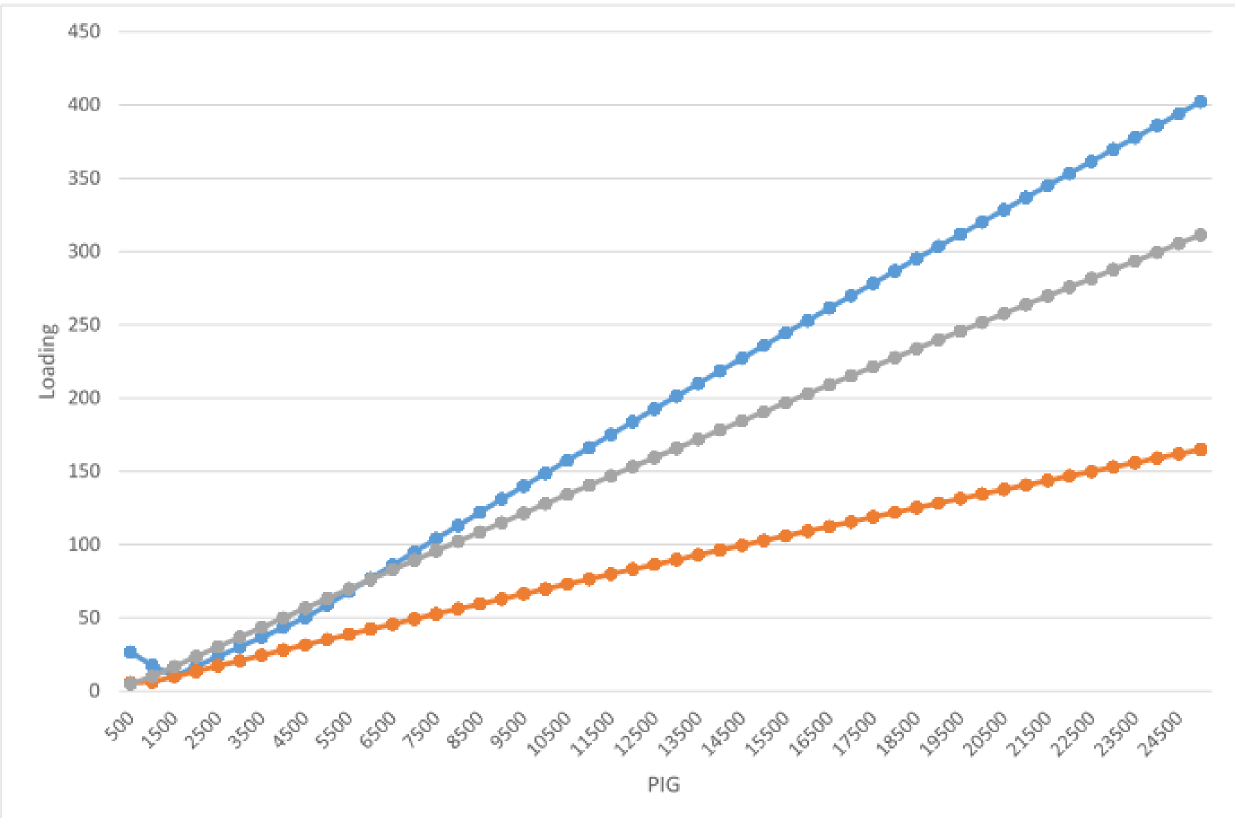
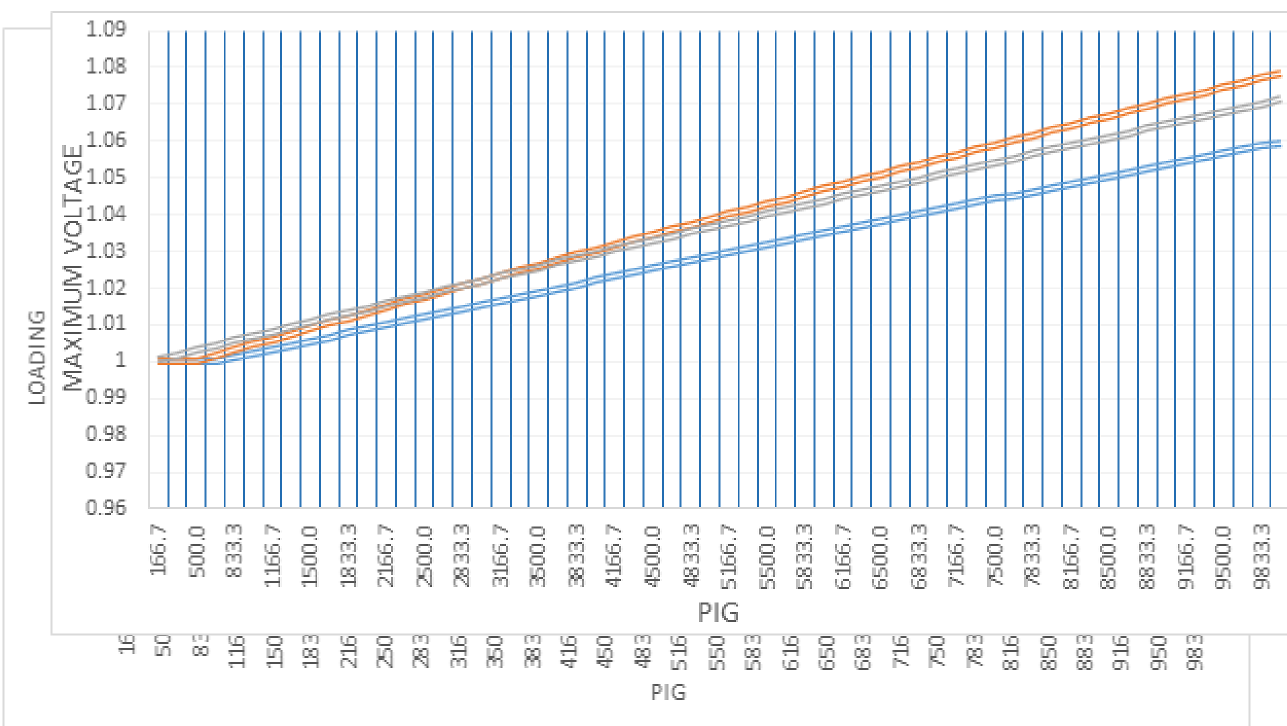


Figure 1.1

In one way secondary feed, the PIG before a violation occur in the voltage and loading is 21.8 kW. This is also called the hosting capacity of the system. For the 2 way secondary feed, 19.2 kW is the hosting capacity and lastly, for the 3 way type, the hosting capacity is 23.5 kW. It is very crucial to know the hosting capacity of a type of secondary feed to know the output rating of RE system to be installed in the houses.

To the extent of knowing the correlation of the location of the embedded generators, another simulation is done at which only one node will be injected with the hybrid system. In the former part of the study, it was discussed that distributing the RE system to the nodes is better than having only one node with injected RE. Consequently, having this conclusion, the researchers want to compare the results obtained from the simulation of injecting the RE system to three worse nodes and injecting it on one node only.



The graph above shows the maximum voltage and the loading versus the PIG of the system. The two simulations depicts the same scenarios, it is both upwardly sloping. But there is a great difference when the hosting capacity is considered. From 21.8 kW, the hosting capacity now is 16.55 kW for 1 way, 17.65 kW for 2 way and 16.5 kW for 3 way. In pursuance of simplification, a hybrid system when installed in only one node, will bring adverse effects in the voltage and the loading. The hosting capacity for the former scenario is lower because it violated the 1.05 mark in a lower PIG.

Other software used (all open source and for public access): SmartDraw, online diagram maker (for the single-line diagram) and LaTeX, equation editor (for formatting the mathematical equations).

MATLAB POWER SYSTEM SIMULATION

A total of 16 codes were programmed in order to simulate the worst case scenario for all hybrid systems and examine the recurring trends based on the results. The main functions that were used in every iteration are **BFSLoadflow**, **power_flow** and **polar**. **BFSLoadflow** takes the load demand power together with the line connectivity data (line resistances and reactances) then performs the backward/forward sweep method for the load-flow computation on all nodes and branches. The output of BFSLoadflow is then input into the **polar** code which transforms the resulting complex branch ampere loading from rectangular to polar form. Finally, the **power_flow** code takes the polar branch ampere loading output of BFSLoadflow and computes its magnitude. The following programs are the other functions in which all the codes above were nested into.

- **iterating_worst_node finder; worst_node_finder:** These codes take the power factor (as the primary identifier of the EG type), testkW (its maximum and increment) and type of distribution network (1-way, 2-way and 3-way) as input then uses conditional loop statements in order to simulate the injection of an embedded generator on each node then perform the load-flow computation for every iteration. In this way, one would be able to analyze the effect of injecting an EG at different nodes that have different distances from the distribution transformer. The results from these codes showed in which node overcurrent and overvoltage first occurs (dubbed as the worst node).

- **max_node:** This code essentially finds the maximum and minimum values of branch ampere loading and per unit voltage level. The results of this code were used to investigate the effect to voltage level, system loss and branch loading.
- **DG_flow:** This particular function takes the maximum hosting capacity as input then divides that value into the total number of loads as the equation for embedded generator model. This code displays the result of the condition when the maximum hosting capacity (in kilowatts) is divided among all nodes. The result of this code was used to compare the behavior of the system when embedded generation is distributed amongst all nodes versus when they are aggregated in one node (single-installation).
- **permn:** The majority of this code was taken from GitHub, an open source community for programmers, to serve mainly as a tool for permutation. It takes a set of elements, number of items per combination and number/s of kth permutation/s that the user wants to store. It outputs a permutation matrix and its corresponding index matrix that has n^n number of rows (permutations with repetition) which represents the total number of combinations where n = size of the power factor array. In the case of solar, wind and biomass hybrid system, there are 3^3=27 combinations. The elements per row in the resulting permutation matrix is then used to simulate the effect when different types of EG are arranged differently on the determined worst nodes per distribution network. For instance, the results showed that when the EG with the lowest power factor is injected to the worst node, the result would be a lower hosting capacity which increases when the EG with the lowest power factor is injected to the second and third worst nodes. In addition, this code can simulate any type of EG too and it can take any number of power factors. This code was essential in testing all types of hybrid combinations (purely solar, solar-wind hybrid, solar-biomass, solar-biomass-wind, etc.) and all the possible arrangements of the injected EG's.

- **all_hybrid; all_hybrid_single:** These functions take the worst node, range of hosting capacity and array of power factors as input then inserts the total hosting capacity as the real power at the selected worst node to simulate single-installation of multiple EG's in one household. The apparent power equation in the form P+jQ, where P is the real power (testkW) and Q stands for reactive power (testkVar) was used to compute for the embedded generators' output using the real power and power factors as input. The total power of the embedded generator injected at the worst node becomes $EG = testkW + (testkVar) * j$ where testkW is the total hosting capacity and $testkVar = testkW * tan(cos^{-1}(powerfactor))$. Compared to **all_hybrid_flow** which simulated the scenario where the total hosting capacity is divided into some of the worst nodes per SDN, **all_hybrid_single** outputs the worst case scenario as all the power factors contributing to the total apparent power are modelled to be connected at only one node.

- **all_hybrid_flow; all_hybrid_worst_node_finder:** These functions take the range of hosting capacity, the array of power factors and the array of worst nodes for different SDN's then inserts $\frac{(total\,hosting capacity)}{size(powerfactorarray)}$ at each of the worst nodes for every SDN. This code can simulate any type of EG; hence, it can take any number of power factors so long as it follows the assumption that the number of installations are less than or equal to the total number of loads. In the case of solar, wind and biomass hybrid system, the equation becomes $Real\,Power = \frac{(total\,hosting capacity)}{3}$ per node. The resulting system parameters from this condition are better than the ones simulated in **all_hybrid_single.**

- **all_gen_tester; iterating_all_gen_tester:** These codes can simulate embedded generators modelled as either induction or synchronous generators by taking an additional array of 1 and -1, which corresponds to the power factor array, as input. Since the cell representing embedded generators take constants testkW and testkVar and inserts them into an equation in this form: $testkW + (testkVar)j$, one has to simply multiply the testkVar by 1 or -1 in order to model different generators as either synchronous or asynchronous. Similar to all_hybrid_flow, these codes can simulate any type of EG and take any number of power factors too.
- **pf_worst_node_finder; iterating_pf_tester:** These functions take a test power capacity and minimum, maximum and increment power factor as input then perform load flow using the set of power factors in order to determine the effect of increasing or decreasing an embedded generators power factor and reactive power.

FUTURE WORK (RECOMMENDATIONS)

This study utilizes a deterministic approach by using constants (power factor, off-peak load profile multiplier and others) to model all types of embedded generators installed at various test circuits (1-way, 2-way, 3-way, residential and mixed load). It would be better to implement this study using a probabilistic approach since there is no way to know the actual power output of an EG and its corresponding load profile every hour. This uncertainty in power output is brought about by the instantaneous changes that may occur due to environmental factors in which renewable energy sources are dependent on (solar irradiance, wind speed and others). However, there is a way to predict or forecast these environmental factors using probability and statistics. For a probabilistic approach, it is recommended to use the Monte Carlo Simulation - a method commonly utilized by existing studies on hybrid systems.

Furthermore, this study also employs an approach that solely involve the use of various power factors to differentiate distinct EG models. However, there are more factors that determine the generated power output of an EG in practice. For instance, in a wind turbine, these factors include the coefficient of performance, mechanical efficiency, generator efficiency and many others. A better approach to this study, especially when examining the transient response of the distribution system to hybrid energy sources, is to incorporate all these other factors in modelling different types of EG.

In addition, it is worth noting that only the worst conditions were selected as test cases (off-peak load and highest generated power) regardless of the actual load and generation on a per-hour basis for this particular study. For instance, this study demonstrates what happens when the highest solar generation happens on the off-peak of residential load profile. This scenario is not always true. The off-peak load and highest generation do not always happen during the same hour. Hence, a better approach would be to consider testing typical renewable power generation per hour to their corresponding hour in a realistic load profile.

Lastly, we modelled wind turbines and biomass generators as induction generators in order to exhibit the worst case scenario for the selected cases. In reality, wind turbines are typically manufactured as synchronous generators for commercial use. Simulating this with a modified program, we found that when modeling EG as synchronous generators, the distribution system performance is better and the maximum hosting capacity is increased. This is due to the lower reactive power that results from leading power factor that is characteristic of synchronous generators.

CONCLUSION

Hybrid systems with machines that have non-ideal (lagging) power factor are detrimental to the distribution system's power quality. The lower the power factor, the more detrimental it is to the distribution network. To minimize the adverse effects of hybrid systems, utilities may opt to offer the customers incentives to use the *alternative* hybrid systems (EG) which were determined to result to least system loss and better voltage quality. Better yet, it is best for both new and continuing renewable energy ventures to innovate smart and efficient hybrid systems that approach the ideal power factor or would improve the present power factor of the existing distribution network.

The degree of the impact of hybrid systems vary for each parameter (loss, loading, voltage). However, since the resources and economic worth for maintenance and repair for each parameter also varies, both factors should be considered as deciding factors when making technical standards and policies.