MODELING AND ANALYSIS OF THE EFFECTS OF PV SYSTEM INTEGRATION INTO EXISTING NEIGHBORHOOD ELECTRICAL DISTRIBUTION SYSTEMS

A THESIS SUBMITTED TO THE GRADUATE DIVISION OF THE UNIVERSITY OF HAWAIʻI AT MĀNOA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

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ELECTRICAL ENGINEERING

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By

Seth Jones

Thesis Committee:

Matthias Fripp, Chairperson

Reza Ghorbani

Olga Boric-Lubecke

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ABSTRACT

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BY

SETH JONES

APRIL 2017

The competing interests of utility power generation companies, residential photo-voltaic (PV) system installers, and residential PV system manufacturers has created an assortment of contradictory viewpoints concerning the capacity of electrical grids to include renewable energy expansion. A frequent conflict created within this environment is that between utility companies, who have the final authority on whether or not to grant PV system installation licenses, and individual home owners and residential developers seeking the energy savings benefits that PV systems can provide for their homes. The general explanation offered by utility companies as the basis for whether or not they grant installation licenses is their estimation of grid saturation on the secondary of the substation that the license applicant is supplied by. While the definition of when a substation has reached its saturation point will vary between utility companies, the saturation point itself is generally determined by a comparison of the estimated minimum expected load on a given substation during the hour of peak PV generation capacity to the rated power of the expected peak PV generation itself during that hour. With there being no current legal requirements for utilities to publish their actual loading or determination assumptions for saturation, home owners and residential developers currently have no established method to contradict the utility company's estimation and provide evidence that their substation can support the introduction of additional PV systems without adverse effects. The intent of this Thesis is to propose a novel, bottom-up modeling approach and to outline the general requirements necessary for the repeatable creation of accurate and flexible simulations that can demonstrate the real world effects of the integration of residential PV systems onto existing electrical distribution systems

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Modeling and Analysis of the Effects of PV System Integration into Existing Neighborhood Electrical Distribution Systems

Seth Jones, P.E.
Electrical Engineering Department Graduate Student
University of Hawai'i at Mānoa
Honolulu, HI 96822
sethj216@gmail.com

Abstract—**The objective of this paper is to outline the general requirements and to formulate a novel procedure for the creation of bottom-up modeling simulations capable of demonstrating the real world effects of integrating residential PV systems onto existing electrical distribution systems. This paper demonstrates the cogency of the steps it proposes by applying its methods through the creation of an actual simulation for a real-life 635 resident neighborhood fed from a substation supplying a nearly equal amount of nonresidential load.**

Index Terms—*Mega Volt Ampere (MVA); Kilo Volt Ampere (KVA); Kilo Volt (kV); Kilo Watt Hour (KWh); Photo-Voltaic (PV); Saturation; Back-Feed; Load; Droop; Apparent Power; Real Power; Reactive Power; Turns Ratio; Per-Unit Base; Tap Changer; Supply Tap*

I. INTRODUCTION

The competing interests of utility power generation companies, residential photo-voltaic (PV) system installers, and residential PV system manufacturers has created an assortment of contradictory viewpoints concerning the capacity of electrical grids to include renewable energy expansion. A frequent conflict created within this environment is that between utility companies, who have the final authority on whether or not to grant PV system installation licenses, and individual home owners and residential developers seeking the energy savings benefits that PV systems can provide for their homes.

The general explanation offered by utility companies as the basis for whether or not they grant installation licenses is their estimation of grid saturation on the secondary of the substation that the license applicant is supplied by. While the definition of when a given substation has reached its saturation point will vary between utility companies, the saturation point itself is generally defined as some ratio of the combined KW rating of PV systems installed on the substation's downstream feeders during their peak generation hour to the substation's estimated combined minimum day-time load.

Currently there are no legal requirements for utilities to publish actual substation loading values or the assumptions they are using for determining their saturation estimates. This has unfortunately resulted in the creation of an atmosphere of mistrust between many home owners and their utility companies because the homeowners have been left with no means to either verify or contradict their utility company's claims. If a reliable and accurate means of simulating the effects of adding PV systems onto existing distribution systems could be developed and made commercially available, it could alleviate uncertainties by all parties and provide a valuable tool for the planning of future PV expansion.

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II. Background

In the spring of 2016, the largest residential provider on Oahu, Hunt Companies, approached University of Hawai'i at Mānoa faculty members with questions on residential PV integration for a neighborhood community they manage on the Pearl City peninsula, located on part of the U.S. Navy portion of Joint Base Pearl Harbor Hickam (JBPHH). Their initial motivation for requesting this analysis was their search for a resolution of the difficulties that they were experiencing with the existing solar thermal hot water heating systems installed by prior ownership in many of their housing units. Citing the high failure rate and maintenance costs of the aging systems, as well as general resident dissatisfaction with their hot water output, they expressed a desire to see what the tradeoffs would be if they replaced the solar thermal panels with modern PV systems and (in anticipation of pushback from utility providers) further asked if a justification could be provided that could illustrate what the maximum amount of PV generation capacity was that could be installed without back-feeding their substation from their Pearl City neighborhood. To facilitate the analysis, Hunt Companies then provided all of their daily reports that contain the hourly KWh meter readings for each of the homes in their neighborhood and facilitated coordination with Navy Facilities Engineering Command (NAVFAC) to obtain all of the neighborhood utility as-built drawings.

The as-built drawings that were provided were location centric "linesman" drawings with power distribution shown by power pole and transformer location overlaid to a map of the neighborhood. While this style of drawing is functional for technicians attempting to locate specific components, its style presented challenges for power flow analysis since many power lines were shown to overlap and share the same pole while having no electrical connection to one another. The prints themselves, while available in electronic form, were only available in picture .PDF form with no electronic search capability. Further complicating the use of the prints was the fact that they had undergone numerous revisions from multiple sources as houses and buildings were constructed in the neighborhood throughout the years using different contractors. Consequently, no official transformer, meter, or power pole naming convention had been adopted, reducing the readability of the prints. Finally, additional challenges were caused by the presence of multiple errors and omissions in the form of the transformers listing incorrect or omitting residents, poles showing meters that weren't there, and a missing revision for the location of the tie in point for a 1000 KVA solar farm that had been installed.

In spite of the challenges, a careful analysis of the as-built drawings revealed that the electrical distribution for the Pearl City neighborhood could be summarized as a single 50 MVA substation source supplying a network of 11.5kV transmission lines feeding both residential and nonresidential loads while operating in parallel with a 1000 KVA solar generation farm. The 635 residential units in the neighborhood were found to have a wide range in floor area size and a total of 31 different floor plans used in their construction. These residential units were found to receive their power from their substation's secondary side 11.5kV transmission lines through a distribution of 87 residential feeder transformers, each having a rated secondary output voltage of 240/120V. The residential transformers themselves were found to supply varying numbers of residents with different combinations of floor plans and ranged in rating size from 37.5 to 250 KVA each, totaling 9,231 KVA combined. Non-residential loads supplied by the 11.5kV transmission lines consisted of mostly U.S. Navy operated office and training facility type structures but also included non-standard loads such as ship's piers and sewage lift stations. Together, the non-residential feeder transformers were found to have a combined rating of 8,613 KVA.

The KWh meter readings that were obtained for this neighborhood were provided through an energy management company with a long standing contract with Hunt Companies. This contractor uses wireless transmitters connected to each resident's KWh meter to send hourly signals to an area receiver for collection. Analysis of the provided data revealed that KWh signals for individual residents would frequently "drop out" and "drop in" at random intervals throughout the day on each report. Often, the drop out times were sufficiently long enough that the transmitters appeared to stop being registered by the receiver all together, resulting in resident addresses being omitted from the subsequent daily reports. Inversely, transmitters that had been dropped off of prior reports were observed to re-register with the receiver, causing new addresses to be added each day to the reports.

III. PROBLEM STATEMENT

Noting the complexity and the number of factors required for determining how much PV could be installed without back-feeding the substation, it was decided that creating a simulation capable of calculating power flow and voltage conditions from the information provided was the only way to fully answer the question posed by Hunt Companies. With the understanding that the Pearl City neighborhood is not the only distribution system seeking the answer to this question and in the absence of an industry standardized model for creating such a simulation, it was sought to develop an approach that could be replicated for other developments. Taking this consideration into account, the following steps were performed to consolidate all of the available information for the Pearl City neighborhood into a single program capable of performing user-input based calculations:

1) As-built drawings were compared to residential records and site visitations were performed to verify which transformers fed which residents.

2) All of the as-built drawing revisions were then consolidated into a single power flow oriented one-line drawing that incorporated the residential corrections.

3) An algorithm with the capability of recognizing and removing zero inputs from meter signal drop-outs was developed to extract hourly loading data for each resident from the provided KWh meter readings

4) All of the residential hourly loading data for each day of each month was then combined into single monthly-consolidated spreadsheets.

5) Hourly loading data for each month was then organized by residential housing unit floor plan so that historical "like-type" mean, median, non-zero minimum, and maximum loading profile data could be extracted for each type of residence for each given month.

6) Actual load rating information was then collected from residential appliances to provide data for manual loading assignments and for the determination of the energy savings provided by the currently installed solar thermal hot water heaters.

7) Nonresidential loading information was collected to the extent it was available and profiling assumptions were derived for these loads based off of industry accepted sources.

8) Solar radiation hourly profile data for the neighborhood location was then gathered from government and academic geological organizations for the determination of typical hourly PV generation capacity profiles for each month.

With the data gathered and organized, it was then possible to create a program with the capability of allowing a user to assign month-specific PV generation capacity and

to assign either manual or historical month-specific like-type loading profiles to residents within their actual grid locations. This allowed the creation of a means to calculate the effects on the substation's feeder transformers from the introduction of variable user-sized PV systems for variable user-set loading profiles. While the program that was created is currently specific to the Pearl City neighborhood, the methodology of its development is repeatable, allowing its concept to be extended to any residential distribution system.

IV. MODEL DEVELOPMENT

A. Concepts

Modeling the effects of adding residential PV generation onto existing feeders necessitates a conceptualization of how power flows from residences to their feeders when PV systems are installed. The residential feeders of the Pearl City neighborhood are all of the design such that their 11.5kV primary is stepped down to 240V with 120V supplied by grounding the center tap of the secondary. Each feeder supplies their residents with two 120V lines that are 180° out of phase with each other and a common ground line.

When a PV system is installed for an individual resident, it is connected to the resident side of the resident's KWh meter. When the PV system is operational, power flows into the grid if the power produced by the PV system exceeds the power demand of the residence and power flows from the grid if the PV system generation is less than the resident's loading. While an individual resident may be back-feeding power onto their feeder transformer's secondary, the feeder transformer itself will not back-feed unless the sum of all of the resident loading is less than the sum of all of the resident's PV generation. This concept is illustrated for the case of a single resident in Fig. [1] and for multiple residents in Fig. [2].
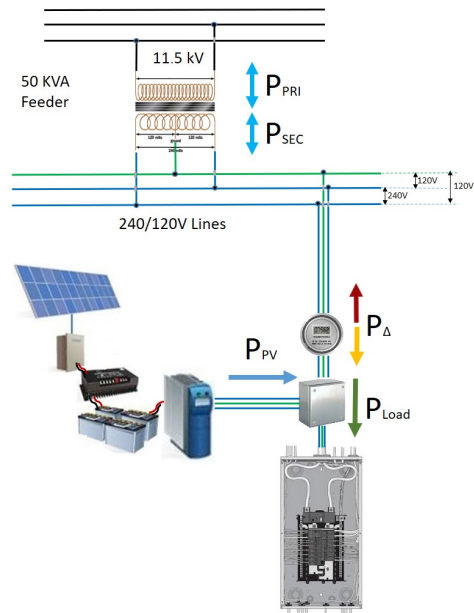
Fig. 1: Typical Residential PV System Connection.

$$P_\Delta = P_{PV} - P_{Load}$$

IF ($P_{PV} > P_{Load}$) → P_Δ flows into the grid

IF ($P_{PV} < P_{Load}$) → P_Δ flows from the grid
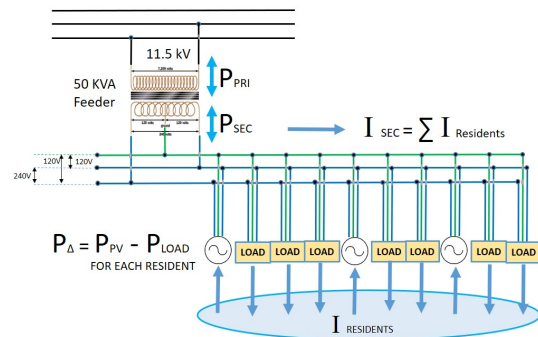
Fig. 2: Multiple residents fed from a common feeder with some residents back feeding power with PV systems and other residents as purely load on the feeder.

The steady state frequency can be considered constant when viewed at the residential distribution level since the frequency of the grid as a whole is maintained actively by utility regulators that control many large, multi-megawatt-rated generators in parallel. The grid itself

employs selective tripping, meaning that loads further downstream in the grid from sources have lower overcurrent trip ratings than loads further upstream to the sources. As a consequence, it is not possible for back-feeding (or even the occurrence of a fault condition) in a residential transformer to affect the steady state frequency of the grid. This can be seen in the case of when PV units are sharing real load with the grid through their residential feeders. Raising or lowering the frequency output of the PV units adjusts their current phase with respect to the grid's and results in the units sharing more or less real load, but does not change the frequency.

Voltage, on the other hand, varies with the amount and type of load that is present on the residential transformer as well as the ratings and droop characteristics of the transformer itself and any other sources that are connected. The droop characteristics observed in residential transformers are caused by winding and hysteresis losses that increase with current and typically range from 1 to 7%, from no-load to full-load (NL-FL), depending on the manufacturer. Large transformers, such as substations, use tap-changers to provide voltage regulation to counter their loss profiles. Tap-changers vary the turns ratio of the transformer itself in response to changes in output voltage, meaning that the substation supplying a group of residential feeders maintains their primary voltage essentially constant, regardless of load.

The actual voltage control characteristics of individual PV units themselves are manufacturer dependent, but nearly all PV units can be classified as having either passive droop or constant voltage control. The voltage profiles of PV units employing passive droop voltage control follow the classic "house-curve" model, with their output voltages pre-programmed to vary proportionately from no-load to full-load current. By contrast, constant voltage control type PV units employ active measures to vary their output voltage equal to or just slightly higher than the grid they are in parallel with.

The influence of individual residential PV sources over the line voltage on the secondary side of their feeders is a function of both their power ratings and their voltage set-points with respect to their feeder's secondary voltage. If the ratings, loading, voltage set-points, and voltage droop profiles for all of the sources and loads on a feeder are known, the steady-state line voltage and the division of load between the sources be calculated. The first case to illustrate how these calculations can be performed would be the "classic" case of a passive droop voltage control type PV unit sharing load in parallel with its feeder. For this example, it is assumed that the PV unit is actively maintaining its output current to inject all of the power it can into the grid and that the PV unit has a linear voltage droop with respect to its output current from NL-FL. To set up the example, the following parameters are assumed:

$S_{PV} = 2\,KVA$ $V_{PV\,NL} = 246V$

NL-FL Droop $\%_{PV} = 3\%$

$S_{FEEDER} = 50\,KVA$ $V_{FEEDER\,NL} = 246V$

NL-FL Droop $\%_{FEEDER} = 5\%$

$P_{LOAD} = 10\,KW$ $pf_{LINE} = 0.8$

With both the power demand of the load and the line power factor known and with the assumption that the PV unit is carrying load to its maximum KVA rating, its share of the real load can be solved by simply dividing its apparent power rating by the line power factor. Where each source falls on its voltage droop curve depends on the amount of current being drawn by the loads it supplies. Since the apparent power of the load is proportional to the amount of current that the load draws, the ratio of the load apparent power to the apparent power rating of the source can be used to find where the actual voltage of the source falls on its NL-FL voltage droop curve. Using S_{BASE} per-unit (PU) analysis, the contribution to line voltage on the secondary from the actual

voltage calculated for each source can be determined by relating their apparent power ratings to the S_{BASE}. This procedure can be demonstrated by the following:

$P_{LOAD-PV} = S_{LOAD-PV} * pf = 2\ KVA * 0.8$

$\quad = 1.6\ KW$

$P_{LOAD-FEEDER} = P_{LOAD-TOTAL} - P_{LOAD-PV} = (10-1.6)\ KW$

$\quad = 8.4\ KW$

$S_{BASE} = S_{FEEDER} + S_{PV} = (50 + 2\ )KVA = 52\ KVA$

$S_{LOAD-TOTAL} = P_{LOAD-TOTAL} / pf = 10\ KW / 0.8$

$\quad = 12.5\ KVA$

$S_{LOAD-PV} = 2\ KVA \quad$ {assumed at rated current}

$PU_{S-PV} = S_{PV} / S_{BASE} = 2\ KVA / 52\ KVA = 0.038$

$S_{LOAD-FEEDER} = S_{LOAD-TOTAL} - S_{LOAD-PV} = (12.5-2)\ KVA$

$\quad = 10.5\ KVA$

$PU_{S-FEEDER} = S_{FEEDER} / S_{BASE} = 50\ KVA / 52\ KVA$

$\quad = 0.962$

Feeder Droop %$_{ACTUAL}$ = Feeder Droop %$_{RATED}$ * $S_{LOAD-FEEDER} / S_{FEEDER}$

$\quad = 0.05 *(10.5\ KVA/ 50\ KVA)$

$\quad = 0.0105$

PV Droop %$_{ACTUAL}$ = PV Droop %$_{RATED}$ * $S_{LOAD-PV} / S_{PV}$

$\quad = 0.03 *(2\ KVA/ 2\ KVA)$

$\quad = 0.03$

$V_{PV} = (1 - $ PV Droop %$_{ACTUAL}) * V_{PV\ NL}$

$\quad = (1 – 0.03) * 246\ V = 238.62V$

$V_{FEEDER} = (1 - $ Feeder Droop %$_{ACTUAL}) * V_{FEEDER\ NL}$

$\quad = (1 - 0.0105) * 246 = 243.42\ V$

$V_{LINE} = V_{PV\ *}\ PU_{S-PV} + V_{FEEDER}*\ PU_{S-FEEDER}$

$\quad = (238.62\ V)*(0.038) + (243.42\ V)*(0.962)$

$\quad = 243.24\ V$

The second case to illustrate how these calculations can be performed would be the case of a single constant voltage control type PV unit sharing load in parallel with its feeder. For this example, it is assumed that the PV unit is IEEE 1547 compliant in that it behaves essentially as current source; injecting its power to the grid at a near unity power factor and continuously adjusting its output voltage to be equal to the voltage sensed on the line. [1] This example also assumes that both the power factor and KW load on the line are known and that the PV unit is supplying its rated current output to the grid. For this example, the following parameters are assumed:

$S_{PV} = 4\ KVA$

$S_{FEEDER} = 75\ KVA \quad V_{FEEDER\ NL} = 244V$

NL-FL Droop %$_{FEEDER}$ = 5%

$P_{LOAD} = 10\ KW \quad pf_{LINE} = 0.8$

Load division for this case can be calculated using the same procedures as for the passive droop case. The voltage calculations, however are simpler in that they do not require S_{BASE} analysis since they assume that V_{PV} is always equal to the voltage of the line, which will be equal to the voltage output of the feeder. This procedure can be demonstrated as follows:

$S_{LOAD-TOTAL} = P_{LOAD-TOTAL} / pf = 10\ KW / 0.8$

$\quad = 12.5\ KVA$

$S_{LOAD-PV} = 4\ KVA \quad$ {assumed at rated current}

$S_{LOAD-FEEDER} = S_{LOAD-TOTAL} - S_{LOAD-PV} = (12.5-4)\ KVA$

$\quad = 8.5\ KVA$

Feeder Droop %$_{ACTUAL}$ = Feeder Droop %$_{RATED}$ * $S_{LOAD-FEEDER} / S_{FEEDER}$

$\quad = 0.05 *(8.5\ KVA/ 75\ KVA)$

$\quad = 0.006$

$V_{FEEDER} = (1 - $ Feeder Droop %$_{ACTUAL}) * V_{FEEDER\ NL}$

$\quad = (1 - 0.006) * 244 = 242.62\ V$

$V_{PV} = V_{LINE} = V_{FEEDER} \quad$ {at the current load}

$V_{PV} = V_{LINE} = 242.62\ V$

$P_{LOAD-PV} = S_{LOAD-PV} * pf = 4\ KVA * 0.8$

$\quad = 3.2\ KW$

$P_{LOAD-FEEDER} = P_{LOAD-TOTAL} - P_{LOAD-PV} = (10-3.2)\ KW$

$\quad = 6.8\ KW$

While these types of calculations are straight-forward, they become increasingly complicated for cases involving multiple PV units in parallel with a feeder. One way to

simplify the analysis is to assume that all of the PV units connected to the feeder have their voltage controls synchronized through some central control mechanism. It should be noted that this is not an unrealistic assumption considering how the rise of distributed generation on the grid in general has created a boon in voltage control communication devices. [2] If the voltage regulators of PV units operating in parallel with one another are using such a system, that means that they can coordinate their respective outputs to better ensure equitable load sharing and voltage stability for the system. This assumption has the special benefit of allowing all of the PV units to be treated as a single source for performing the load division and line voltage calculation procedures previously shown.

The addition of more PV units; however, brings with it the increased likelihood that their combined generation will exceed the available load on the feeder and result in the feeder back-feeding power to its primary side. An example of how to calculate the load divisions, amount of power back-fed to the grid, secondary line voltage, and the contributions to the primary from such a scenario is provided by the following:

Feeder Np:Ns = 47.92

S_{PV1} = 3.5 KVA S_{PV2} = 4.5 KVA S_{PV3} = 5 KVA

S_{FEEDER} = 50 KVA $V_{FEEDER\ NL}$ = 246V

NL-FL Droop % $_{FEEDER}$ = 5%

P_{LOAD} = 10 KW   pf $_{LINE}$ = 0.8

$S_{PV-COMBINED}$ = "S_{PV}"   {for formula notation brevity}

S_{PV} = S_{PV1} + S_{PV2} + S_{PV3}

   = (3.5 + 4.5 + 5) KVA

   = 13 KVA

P_{PV1} = S_{PV1} * pf = 3.5 KVA * 0.8 = 2.8 KW

P_{PV2} = S_{PV2} * pf = 4.5 KVA * 0.8 = 3.6 KW

P_{PV3} = S_{PV3} * pf = 4.5 KVA * 0.8 = 4 KW

$S_{LOAD-TOTAL}$ = $P_{LOAD-TOTAL}$ / pf = 10 KW / 0.8

   = 12.5 KVA

$S_{LOAD-PV}$ = S_{PV} = 13 KVA   {assumed at rated current}

$S_{LOAD-FEEDER}$ = 0   {note that the feeder is being back-fed and supplying no load}

$S_{BACK-FED}$ = $S_{LOAD-PV}$ - $S_{LOAD-TOTAL}$

   = (13 – 12.5) KVA

   = 0.5 KVA

$P_{BACK-FED}$ = $S_{BACK-FED}$ * pf = 0.5 KVA * 0.8

   = 0.4 KW

Feeder Droop % $_{ACTUAL}$ = Feeder Droop % $_{RATED}$ * $S_{LOAD-FEEDER}$ / S_{FEEDER}

Feeder Droop % $_{ACTUAL}$ = 0   {because the feeder is supplying no load its output voltage is its NL value}

V_{PV} = V_{LINE} = V_{FEEDER} {at NL}

V_{PV} = V_{LINE} = 246 V

V_{PRI} = Feeder Np:Ns * $V_{SEC\ ACTUAL}$

   = (47.92) * 246V = 11788.32 V

The contribution of this primary voltage to the 11.5 kV transmission line as a whole can be calculated using S_{BASE} analysis that treats the back-feeding feeder as a 0.5 KVA source supplying 11,788.32 V. If this source were then placed in parallel with a 50 MVA substation with an actual output voltage of 11.5 kV, the voltage on the line of the feeder's primary side can be calculated as follows:

S_{BASE} = S_{FEEDER} + $S_{SUBSTATION}$

   = (0.5 + 50,000)KVA

   = 50,000.5 KVA

PU $_{S-FEEDER}$ = S_{FEEDER} / S_{BASE}

   = 0.5 KVA / 50,000.5 KVA

   = 0.00001

PU $_{S-SUBSTATION}$ = $S_{SUBSTATION}$ / S_{BASE}

   = 50,000 KVA / 50,000.5 KVA

   = 0.99999

V_{PRI} = V_{FEEDER} * PU $_{S-FEEDER}$ + $V_{SUBSTATION}$ * PU $_{S-SUBSTATION}$

   = (11.788 kV)*(0.00001) + (11.5 kV)*(0.99999)

   $\cong$ 11.5 kV

As can clearly be seen, the effect on voltage for the 11.5 KV line for such a case

is negligible. While significant changes to the 11.5 kV line could occur with many elements back-feeding under low loading conditions, it should be noted that the substation's tap changer would compensate and overwhelm their effect.

B. Power Flow One-Line Schematic

With the aim of creating a program capable of simulating electrical conditions for the entire Pearl City neighborhood, an interactive power flow one-line schematic was developed referencing a combination of utility as-built drawings provided by NAVFAC, residence listing information provided by Hunt Companies, and a series of actual site visitations for accuracy verification. Initially, development of the schematic was attempted using PSIM-10 64 bit, but this approach was abandoned because of challenges encountered with setting up time variant load profiles on the feeders and because a simulation produced from this program would require users to purchase and install software as well as to become familiar with its operation. Since the resident loading profiles that had been derived from the KWh meter readings provided by Hunt Companies had been created using formulas from Microsoft Excel, it was decided that the schematic itself would be most useful if incorporated into a separate tab within a combined .XLSX document utilizing this data. This approach had the special benefit of allowing "meter cells" to be added to the schematic for displaying the power and voltage characteristics specific to each resident and feeder as they are calculated for the user selected loading and PV profiles. This was accomplished by linking these cells to cells on other tabs that receive the user inputs and perform the calculations. An example of how this was designed to appear for the schematic that shows the four transformers supplying the residents of Pearl City Housing Area 1 is shown in Fig. [3].
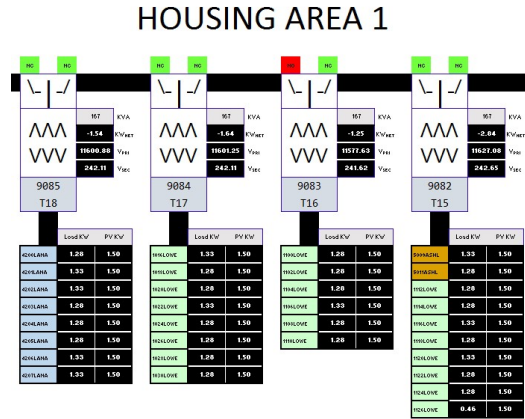
HOUSING AREA 1

Fig. 3: One-line power flow drawing representation of residential transformer feeders supplying residents in Pearl City Housing Area 1.

Transformers and switches within the schematic are represented by graphical symbols with adjacent cells containing their rating and loading information. While each transformer was assigned a schematic number for the purposes of program organization (the numbers 9085, 9084, 9083, 9082 shown on Fig. [3]), the as-built drawing names for the transformers were also included (the designations T18, T17, T16, and T15 shown on Fig. [3]) to facilitate cross-referencing. It should be noted; however, that the majority of transformers on the as-built drawings were unnamed and that for these cases, the nearest pole name was used for this block. The residents powered by the transformers are listed below their respective transformer graphics. The address listings for each resident are color-coded by their street name and have both their current loading and PV generation assignments displayed next to them.

The overall layout of the schematic was created by tracing the as-built drawings pole-by-pole and redrawing them for power flow functionality. This was accomplished by following the many line overlaps out to their origin poles and rearranging the lines to remove the cross-overs while maintaining an accurate representation of their electrical connections. An example of some of the challenges this imposed was the case of the

lines surrounding pole 1M, shown in Fig. [4] and Fig. [5].
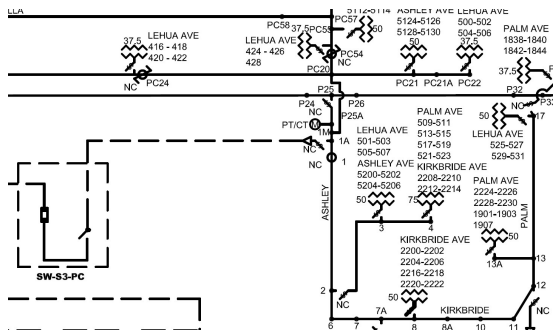
Fig. 4: As-built drawing representation of pole 1M and the poles in its immediate vicinity.
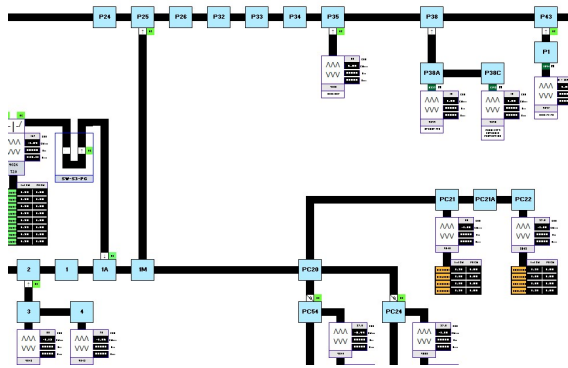
Fig. 5: Power flow schematic representation of pole 1M and the poles in its immediate vicinity.

Fig. [4] displays pole 1M (shown with a PT/CT meter installed) connected to pole 1A directly by line, to pole P25 through a switch, and to pole PC20 by a line overlapping the P25 line. A site visitation verified the accuracy of the connection arrangement shown on the as-builts but revealed that the PT/CT meter had never been installed at the pole. Fig. [5] shows how this circuit was redrawn with each pole represented as a blue box (named by its as-built name) and having black lines to show each pole's interconnections. Fig. [5] represents pole 1M as an electrical "branch off" from the main line through the switch on pole P25 and shows its relations to poles 1A and PC20 as being further sub-branches. Representing the distribution system through this "power flow functional" arrangement makes the drawing much more readable and

allows for more intuitive power flow relationship understanding.

C. Like Type Residential Hourly Profile Development

Extracting loading data from the KWh readings that were provided required the setup of an algorithm to smooth out the missing data and return the difference between each hour's reading as the amount of KWs demanded by each resident for that hour. Since the hourly KWh meter readings were provided in a Microsoft Excel .XLSX tab, Excel functions were used for this task. One of the most important requirements for using his approach was that all of the data had to appear on the same relative rows for each day's report so that Microsoft Excel's iterative formula writing capabilities could be used. Because residents appeared to drop off and onto the provided reports randomly each day, this required the employment of a sorting filter. To accomplish this, an Index/Match formula was applied to cells in a tab titled "Intermediate" which targeted cells in another tab titled "Copy". The provided KWh reading data was then copy/pasted to the targeted cells in the "Copy" tab, allowing the formulas in the intermediate tab to automatically sort and return each day's KWh meter readings in the specified order for use in analysis. The ordered data was then copied to another tab titled "Analysis" where cells in the columns adjacent to each KWh meter reading data row were provided with formulas to calculate the loading for each hour of the day for each resident.

Since meters for residents occasionally dropped out (returned zero values in place of a meter reading) during the course of the day, the formulas for the load calculation cells had to contain "if" statements to determine whether the cells they were taking the KWh readings from were in fact cells containing valid meter readings. These formulas were constructed such that if the formula cell sees

that the meter reading provided for both the current hour and the hour before has not dropped out, the formula cell simply subtracts the latter from the former and displays the difference. If the formula determines that the meter reading for the current hour has dropped out, it finds the cell with the first non-zero reading before and the cell with the first non-zero reading after the current hour and then returns the average over the period by taking the difference between the readings of these two cells divided by the number of hours that the meter was dropped. If the formula cell sees that the meter readings have been zero for all prior readings of both the current day and the day before, the formula returns the text "N/A" so that these "bad" loading zeros are not counted by later loading-statistic averages.

With hourly usage calculated and "bad" zeros filtered, the loading data for each resident can be considered in a condition that is ready to be analyzed. Noting that electrical consumption for individual residents is a function of both the size and layout of their home, it was decided that the best way to create "typical" loading profiles was to put the loading data for the residents into groups sorted by their construction floor plans. Sorting the data in this way ensures that any statistic taken from each group was an "apples-to-apples" like-type comparison of only residents that live in homes with the same square-footage area, the same number of bedrooms, and the same living space configuration.

Since the usage tables were constructed with the resident floor plans listed on the same row as their respective address numbers and hourly usage data, a different Index/Match filter was applied to cells in another tab to target the cells containing the usage data and sort them by their floor plan. With the loading tables now grouped by floor plan, cells with other formulas were then created to determine the mean, median, mode, maximum, minimum, and minimum non-zero loading for all occupants of each like-type for each hour of each day. These

daily values were then averaged over the span of their respective months and plotted. Complete results for the values calculated for the month of December 2016 are provided in Appendices [A] and [B]. The plot showing only the mean hourly loading values for each residential unit floor plan in Pearl City for the month of December is shown below in Fig. [6]:
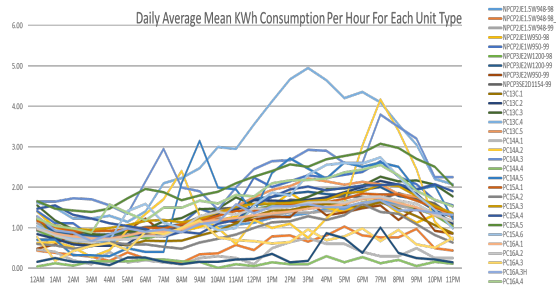
Fig. 6: Mean hourly loading data for each residential unit floor plan in Pearl City for the month of December 2016.

D. Manual Loading Assignment Model

Recognizing that there are conditions where a user simulation may need specific loading conditions that do not necessarily correspond to historical statistics, a model for creating artificial loading conditions using data derived from real loads was developed. A survey was performed in which multiple housing units were visited so that photos of the label plates for their major appliances could be taken. A table was then constructed, Appendix [C], that listed the rated KVA of every appliance and outlet followed by its "running load" KVA multiplier assumption with a written description of its basis. The "running load" multiplier assumption was used with the understanding that the label plate power ratings for each appliance represents the appliance's maximum design power draw and were based on a combination of NFPA 70 code citations and physical observations. An example of the label plate for an electric range is shown on Fig. [7].

14
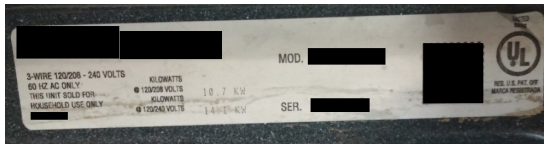
Fig. 7: Photo of the ratings label plate for one of the electric ranges installed in Pearl City.

	Maximum KVA Assumption	Multiplier For Running KVA	Nominal Running KVAh	Hourly Run Time Multiplier
Dryer	5.00	0.50	1.88	0.750
Washing Machine	1.50	0.75	0.84	0.750
Garbage Disposal	1.59	0.50	0.00	0.005
Dishwasher	1.08	0.75	0.41	0.500
Microwave	1.80	0.75	0.07	0.050
Range	14.10	0.25	1.76	0.500
Air Conditioner	5.13	0.50	1.28	0.500
Water Heater	4.50	0.95	0.53	0.125
Refrigerator	0.75	0.25	0.09	0.500
Lighting and Recepticals	13.11	1.00	13.11	1.000

Fig. 8: Input cells for the hourly run time multiplier for Pearl City resident appliances.

On this label plate, the manufacturer is stating that its maximum power rating for the range is 14.1 KW or 14.1 KVA since it is a purely resistive load consisting only of heating elements. Noting that the physical construction of this particular electric range consists of upper and lower interior oven heating elements and four stove top burners, it can be assumed that the maximum power draw for the range will only occur during the "heat-up" process immediately following activation of their controls to their maximum settings. This would be akin to a user setting a cold oven to "broil" while simultaneously turning all four burners on the stove-top to "high". Noting that typical usage for a range involves the use of only a couple of burners or setting the oven to a bake (not broil) setting, a value of 0.25 was assigned to the "running load" multiplier.

In order to extract KVAh from running KVA it was determined that an hourly running multiplier needed to be applied. For the case of the electric range, even if it was turned on and ran only during one given hour, its burners and heating elements turn off and on periodically within the set points of their program temperature, meaning that they do not draw their "running KVA" continuously. Furthermore, it should be noted that use of an electric range to accomplish a typical cooking task is generally in the order of 15 to 45 minutes. Recognizing the subjective nature of making run-time assumptions, this was left as a user variable input for load calculations. The input and calculation cells for the run time multipliers for Pearl City resident appliances are shown in Fig. [8].

A control panel table was then created that has "on, off" selector cells that are used by other cells in their respective columns to add or remove the "running-load" and "run-time" corrected KVA values for each appliance turned on by the user. It is important to note that for the more complex challenge of forecasting the load demand from lighting and receptacles, the multipliers for both running load and run time assumptions have assumed full rated power carried forward to this point. In place of an "on, off" selector, the "Lighting and Receptacle" load assignment cells allow the user to manually assign a decimal multiplier from 0 to 1 in the control table to represent this load. Embedded notes are placed within these cells to explain to the user that assigning a value of "1.0" would be a claim that the lighting and receptacles for the residence were drawing 13.1 KW. In order for them to draw that much power, every light in the residence would have to be turned on and every outlet for the residence would have to have significant power drawing devices plugged into it. For day time loads, more reasonable assumptions for this load are on the order of between 0.05 to 0.2.

Additional cells on other rows within each column allow the assignment of blanket power factor assumptions for the resident and calculate the real power and apparent power from the load selections. The columns themselves for the table are organized by housing unit type, which allows a simulation using the loading data assigned to the table to be selected and applied to all houses of the same floor plan. A picture showing the "on, off" controls,

power factor assignments, and power calculations for the first three floor plans is shown in Fig. [9].

	NPCP2JE1.5W948-98	NPCP2JE1.5W948-98_4	NPCP2JE1.5W948
S Load (KVAh)	4.23	6.33	7.26
P Load (KWh)	**3.38**	**5.38**	**6.18**
Q Load (KVARh)	2.54	3.33	3.83
PF Load (lagging)	0.80	0.85	0.85

P Load is auto-calculated based on inputs from the residential load

	NPCP2JE1.5W948-98	NPCP2JE1.5W948-98_4	NPCP2JE1.5W948
Dryer	OFF	ON	ON
Washing Machine	OFF	OFF	OFF
Garbage Disposal	OFF	OFF	OFF
Dishwasher	ON	OFF	ON
Microwave	OFF	OFF	OFF
Range	ON	ON	ON
Air Conditioner	OFF	ON	ON
Water Heater	OFF	OFF	ON
Refrigerator	ON	ON	ON
Lighting and Recepticals	0.15	0.10	0.10

Fig. 9: "On, off" controls, power factor assignments, and power calculations assignable to the first three Pearl City floor plans.

E. PV Generation Profile Development

In order to create a simulation that can accurately show the effects of adding PV into a system, a calendar month specific solar radiation profiling model was created using data obtained from the University of Hawai'i at Manōa Geography Department website titled " Solar Radiation of Hawai'i". [3] This website allows a user to click on a specific location and view its "clear-sky" recorded solar radiation in watts/m² for user selected times. Using this data, a table was constructed to show the average solar radiation for each hour of the day for each month at the Pearl City neighborhood. It was noted from this data that solar radiation peaked each day at 1:00 PM for every month of the year and that the month of July was the month that received the highest solar radiation.

For the creation of a simulation in which a user can assign KW rating values to a PV unit that they would like to observe the effects of adding, it must be assumed that the KW assignment was for the maximum output at peak power generation since that would be the basis for the ratings of any actual inverter units and solar panels that would be installed.

In order to create an hourly profile, the peak hour KW assignment was multiplied by scalar multiples that were assigned to each hour based off of the hourly radiation profile that they received in that location. These values were then further multiplied by another scalar multiple that reflects the changes in solar radiation levels at that location for each month.

A second table for computing average solar generation capability multiples was then constructed with a value of 1 assigned to the 1:00 PM column for each month while the remaining multiples were calculated by dividing the solar radiation received at every other hour by the 1:00 PM values for each month. Another multiple was then calculated to create a means to scale the radiation received during non-July months by dividing each month's 1:00 PM solar value by the July 1:00 PM value. With these values obtained, accurate generation profiles can be calculated by writing formulas in cells to link the correct multiple value to the correct times and multiply them by the user input KW asssignment.

F. Solar Farm and Nonresident Loading Profiles

Adding to the complexity of the challenges of creating a simulation was the presence of a solar generation farm and a substantial amount of nonresident load powered from the same 11.5kV lines shared by the Pearl City neighborhood. Although no actual loading data was available for the nonresidents, both descriptions of what the nonresidential loads were and the KVA data for their feeders was available. This allowed for reasonable assumptions to be made for their loading profiles using observation and industry sources.

With all of the solar farm rating information available, its output was considered a known quantity and its generation profile was assumed to follow the solar radiation profiles described for the PV systems. The nonresident loading was a little

more complex because there were four distinct groups that the loads could be place into for profiling purposes. The largest group, by KVA rating, consisted of U.S. Navy operated office and training school house buildings. The simulation produced for this paper assumed that these buildings follow typical office building loading profiles like those described in Reference [4]. The next largest group were the ship's piers located on the peninsula. Since the load on a ship's pier is almost entirely due to the ships themselves, their loading profiles were assumed to follow the U.S. Navy ship's-in-port loading profiles described by Reference [5]. The third group of nonresidential loads were the feeders supplying the numerous sewage lift stations located on the Pearl City peninsula. Noting that the operating profiles for this type of load would follow the human occupancy on the peninsula, it was assumed that the loading profile for the sewage lift pumps would resemble a combination of the office building and resident demand profiles. The fourth and final group of nonresident loads were the feeders supplying the street lights. These loads were assumed to follow daylight hours where their profile was simply "on" during the evening hours and "off" for the daylight hours. With the loading profile data available from References [3] and [4] as well as the availability of residential loading profiles, the multiple tables to represent loading profiles for all four types of nonresidential loads were then created using the same methods described for the solar generation profile multiples.

G. Solar Thermal Hot Water Heater Load Savings

The calculation of energy savings that Hunt Communities currently has from their solar thermal hot water heater heating units required the incorporation of a number of variables. The first variable for this calculation required knowing the total number of houses with solar thermal systems installed and operating. Since Hunt Communities did not have this information

available, it was decided to construct the program such that the user was allowed to select the number of houses with hot water heaters installed as the information becomes available and then apply a usage factor to reflect solar thermal systems that were down for maintenance as well as to factor in user compliance.

The next program variable was ratings information for both the electric heating elements installed on the water heaters and the circulation pumps for the solar thermal systems. The simulation that was developed assumed that if the solar thermal systems were removed, the electric heating elements would be the only input and would therefore run in place of the solar thermal system. After looking at several of the housing units it was determined that all of the heating elements that were installed for these water heaters were sized at 4.5 KVA for 240V inputs and that the circulation pumps for the solar thermal systems were sized at 6 watts. Due to the considerable difference between their values, the solar thermal pump running values were neglected.

Since the solar thermal systems are programmed to a default setting that has the system run between the hours of 6 AM to 8 PM each day, creating a model to determine the energy savings they provide required the creation of a running profile for an equivalent electric heating element for the same period. Fig. [10] shows the load profile that was observed over a 14 hour period for a 4.5 KW electric hot water heater servicing a 50-gallon tank for a residential home [6].

(a)

According to Reference [6], run-time for water heating elements varies with the water demand and typically ranges between 3 and 15 minutes. Additionally, water heating elements will turn on periodically with no water demand, as shown by its approximately 6-minute operation just before 2PM, to maintain the temperature of the tank. Adding all of the run-time shown on Fig. [6] between the hours of 6AM and 8PM shows that the heating elements were on for approximately 40 minutes during that period, meaning they used approximately 3 KWhs. It should be noted that this estimate may be low for the residents of the Pearl City neighborhood since most of the homes are occupied by families with young children and at least one stay-at-home spouse. A conservative estimate would be that the water demand would entail at least one laundry load and at least two more sink demands for home meals during the period. If washing machine demand were assumed to be 10 minutes and the two additional sink demands were assumed to be 5 minutes each, the total run time estimate would increase to 60 minutes and the estimated KWh savings would increase to 4.5 KWh per resident. If all 635 residents have solar thermal hot water heating systems installed with no units down for maintenance and full residential compliance with the 6AM to 8PM operational guidelines, the total energy savings from the solar thermal systems would be 2857.5 KWh per day.

H. Simulation Control Panel Development

With a working power flow schematic, the availability of historical residential loading profile data, a means to create accurate manual residential load profiles, the availability of solar generation profile data, and with nonresident profile data available, it became possible to set up a control panel for introducing user input data. To facilitate formatting the control panel, three "support tabs" were created to manage the data and execute the formulas necessary for its displays. The first support tab is the tab titled "Manual Load Selector". This is the tab described in Section II [D] of this paper that contains the loading input for all houses of any floor plan whose load profile selector is selected to "Manual".

The second support tab is a tab that is hidden from the user by use of the "Protect Workbook" feature and is titled "Selector Data". As the name suggests, this tab contains the tables containing the historical hourly like-type loading values, the tables containing the solar radiation profiles and hourly multiples for each month, and all of the arrays used for input to the various selection cells of the "Control" tab. This tab also contains a special formula table which is linked to the "Control" tab load profile selector for each resident like-type and fills in its values from whether the mean, median, minimum non-zero, or maximum value is selected. If the load profile is selected to manual for a given like-type, the corresponding table cells will link to the "Manual Load Selector" tab and obtain the value currently assigned to the unit's like-type. An adjacent table multiplies the number of houses of the given like-type times the user selected values from this formula table and returns the total loading value for each hour for each unit like-type for the load profiles selected. With like-type selected resident loading profiles established, all values for each hour are summed and a total loading profile multiple is created with a value of 1 assigned to 1:00 PM. It is important to note here, that the summed values themselves are not used directly for the hourly residential loading totals to allow for manual overriding of the like-type blanket assignments on another tab. The profile multiples created are then linked to a table sorted by month to allow formula cells on the control panel to use Index / Match functions to select which multiple is used

based on what month is selected on the control panel.

The third support tab titled "Resident Load Assignment" is the tab where the user loading and PV assignments are made for use in the formulas. This tab contains cells in its top row for the global assignment of Power Factor (pf), PV output voltage, and nominal rated voltage droop. The remainder of the tab is organized by transformer number, with loading and PV generation assignments from the control panel providing the inputs for all of the loads. Residents have an additional option to override their global assignments on this tab by selecting "Individual Mode Enable", as seen in Fig [11].

	A	B	C	D	E	F	G	H	I	J	K
20											
21	XFMR Number	9004								KW_NET	6.00
22	Print Name/Pole Number	PCD16	LOAD KW	6.00	PV KW	0.00				V_PRI	11500.00
23	KVA Rating	50								V_SEC	238.20
24	NOTES: Flood Lights V1, V2 Docks										
25											
26	XFMR Number	9005								KW_NET	-1.71
27	Print Name/Pole Number	T1	LOAD KW TOTAL	23.79	PV KW TOTAL	25.50	KVA	-2.13		V_PRI	11634.40
28	KVA Rating	250	LIKE TYPE ASSIGMENT		INDIVIDUAL	INDIVIDUAL MODE ASSIGMENT		ACTUAL ASSIGMENT		V_SEC	242.80
29	NOTES: LEYC Residents		LOAD KW	PV KW	MODE ENABLE	LOAD KW	PV KW	LOAD KW	PV KW		
30	0100LEYC	PC15A.1	1.32	1.50	OFF			1.32	1.50		
31	0102LEYC	PC15A.3	1.41	1.50	OFF			1.41	1.50		
32	0104LEYC	PC15A.1	1.32	1.50	OFF			1.32	1.50		
33	0106LEYC	PC15A.3	1.41	1.50	OFF			1.41	1.50		
34	0108LEYC	PC15A.1	1.32	1.50	ON	2.00	3.00	2.00	3.00		
35	0110LEYC	PC15A.1	1.32	1.50	OFF			1.32	1.50		
36	0112LEYC	PC15A.3	1.41	1.50	OFF			1.41	1.50		
37	0114LEYC	PC15A.3	1.41	1.50	OFF			1.41	1.50		
38	0116LEYC	PC15A.1	1.32	1.50	OFF			1.32	1.50		
39	0118LEYC	PC15A.5	2.12	1.50	OFF			2.12	1.50		
40	0120LEYC	PC15A.5	2.12	1.50	OFF			2.12	1.50		
41	012LEYC	PC15A.3	1.41	1.50	OFF			1.41	1.50		
42	0152LEYC	PC15A.1	1.32	1.50	OFF			1.32	1.50		
43	0154LEYC	PC15A.1	1.32	1.50	OFF			1.32	1.50		
44	0156LEYC	PC15A.1	1.32	1.50	OFF			1.32	1.50		
45	0158LEYC	PC15A.2	1.24	1.50	OFF			1.24	1.50		
46											
47											

Fig. 11: Layout of a transformer on the Resident Load Assignment tab.

All transformer sections on this tab contain their number, as-built name or pole number, KVA rating, and a notes section to describe their primary load. Residential transformers also list the address and like-type of every resident that they supply and use three sets of columns to represent their loading and PV assignments. The values in the first set of columns utilize an Index / Match function to return the value selected on the control panel that matches the like-type named on their adjacent cells. The second set of columns must be enabled by turning the "Individual Mode Enable" selector to "on". This shades in the like-type values and uncovers the individual assignment values, which can be selected by the user. The third column set titled "Actual Assignment" contains an "if" condition to select either the like-type values or the individual values depending on the individual mode selector position. The "Load KW Total" and "PV KW Total" cells above these entries sum only the "Actual Assignment" columns. For nonresidential transformers, these blocks are linked to their assignment on the "Control Panel" tab.

To the right, of these columns a cell titled "KW_NET" takes the difference between the "Load KW Total" and "PV KW Total" cells. The cells below use per-unit S_{BASE} and droop calculations to determine secondary voltage and the voltage induced on the primary side if the transformer is back-feeding. If the transformer is back-feeding, further cells use per-unit S_{BASE} calculations to determine that transformer's contribution to the 11.5kV line voltage in parallel with the substation. The "KW_NET", "Load KW Total", "PV KW Total", "Secondary Voltage" cell, and each resident's own "Actual Load Assignments" cells for each transformer are linked to their respective transformers on the tab containing the one-line power flow schematic. The "KW_NET", "Load KW Total", "PV KW Total", "Secondary Voltage" cell, and "Primary Voltage" cell for each transformer is linked to the transformer display section of the "Control Panel" tab to provide a "birds-eye view" of the voltage and power parameters for all transformers.

A picture of the final design of the "Control Panel" tab is provided in Appendix [D]. With the desire to make using the control panel as easy and intuitive as possible, a single page setup was chosen, with user input cells displaying their numbers in black and with locked cells that contain formulas displaying their numbers in blue. At the top left corner, a selector cell (that is used for comparison by other formula containing cells) allows the user to pick which month's loading and solar generation curves are to be followed for loading and generation calculations. Below this cell are two cells that allow the user to set the nominal primary side voltage supplied from the substation and the nominal secondary output voltage supplied by all residential

transformers. Below this cell is a cell linked to a formula-containing cell that calculates the unregulated 11.5kV transmission line voltage at the time of peak PV generation. This formula uses per-unit S_{BASE} calculations to weigh the voltage contributions from any back-feeding transformers as detected by the formula cells on the "Resident Load Assignment" tab.

The data column set immediately to the right of the month selector displays the total daily residential load, the residential loading value when at peak PV solar generation, the net residential loading at peak PV generation, and the peak PV nonresidential load. The next data column set displays the substation, total residential load, and nonresidential load transformer KVA ratings. The far right column set adds the total amount of PV generated for the day, the contributions from the assigned residential PV as well as the solar farm to the peak PV, and shows the total amount of PV generation in KWhs that exceeded residential loading during the peak hours. This column set also includes the estimated amount of KWhs saved by the number of residential units selected to be using solar thermal hot water heating units and allows the user to enter a solar thermal usage factor which takes into account assumed user compliance with the nominal 6:00 AM to 8:00 PM settings as well as any solar thermal systems that might be down for maintenance.

The following section contains the cell values that are used to formulate the residential loading, PV generation, and non-residential loading curves. The first row takes the sum of all residential and nonresidential PV assigned by the user and multiplies this sum by the selected hourly generation profile multiple for the selected month and the monthly radiation correction multiple calculated on the "Selector Data" tab. Similarly, the second row computes hourly residential loading by multiplying the total residential loading from the "Resident Load Assignment" tab times the residential load profile multiple assignment for the selected month from the "Selector Data" tab.

The third row titled "Residential Load Profile With PV (No Storage)" simply takes the difference between each hour's residential load and PV generation. The fourth row titled "Residential Load Profile With Balanced Storage" has a hidden outside formula cell that adds the total amount of KWh that was over-produced for that day. The cells on this row then return the difference between the resident loading and PV generation for each hour but display a zero on the hours that the difference is negative. On the cell corresponding to the first hour when load exceeds the PV generation rate, the cell returns the difference plus the over-produced total divided by the number of hours of under production to show the effect of what adding battery storage with some kind of back-feeding limitation would look like. The fifth row returns the sum of the nonresidential loading groups, each multiplied by their respective non-residential loading profiles located on the "Selector Data" tab and within hidden rows on the "Control Panel" tab. The sixth row adds the values on the "Residential Load Profile With PV (No Storage)" row to their respective hourly values on the nonresident load row. The last row adds the "Residential Load Profile With Balanced Storage" values to the nonresident ones. The values of all seven of these rows are represented on the two curve plots located on the following rows, with the first plot showing only the residential loading and PV generation related values and the second plot showing when the residential values are combined with the nonresidential ones.

Below and to the left of these rows is the "Like Type Global Assignment" section. This section is organized with all the floor plan names for all of the like-types listed on the left and has cells to select the load profile, assign PV generation, and assign the number of houses with solar thermal hot water heaters for each like-type listed on the right. The "Load Assignment" column is a formula linked column that returns the value from the "Selector Data" table based on the load profile selected. The user can select any

PV assignment up to 10 KW for each resident and can assign anywhere from zero to up to the maximum number of houses installed for that floor plan to have solar thermal hot water heaters.

Below these rows is the nonresident loading section. This section lists all nonresidential loads supplied by the Pearl City substation on its left hand column followed by the KVA rating of their respective feeders. The right hand columns allow a user to enter any numerical value for loading or PV generation up to the value of the nonresidential load's KVA rating. These values are linked to cells on the "Resident Load Assignment" tab for total loading calculations and further linked to their respective transformer locations on the one-line power flow schematic.

V. SIMULATION RESULTS

With the simulation for Pearl City complete, scenarios were set up to find tipping points where the peak PV generation rate exceeds the available residential loading demand and where it exceeds the total loading on the substation. All scenarios assumed that the solar farm was operating at a rated 500 KW output and that nonresidential loading at peak PV generation was equal to 12% of their respective feeder KVA ratings. Additionally, these scenarios used only the mean loading and PV generation profiles taken from December 2016 and January 2017.

Looking at the month of January, the simulation shows that up to 503.08 KW of rated PV generation capacity could have been installed without residential loading ever falling below the PV generation rate and that this value could be increased to as much as 1,530.85 KW without back-feeding the substation if nonresidential loading were taken into account. Looking only at residential loading, the PV generation capacity could be increased to as much as 1,414.42 KW if 2,878.59 KWh of storage were included with the units and the PV

introduction rate was spread over the evening peak loading demand hours.

The generally higher loading values recorded for the month of December showed an even more optimistic amount of PV that could be installed. The simulation showed that up to 1645.18 KW could be installed without back-feeding the substation if both residential and nonresidential loading was taken into account and that up to 613.83 KW could be installed without exceeding the resident demand.

For the question by Hunt Companies on the trade-offs for replacing the solar thermal hot water heaters, scenarios looked at what the maximum daily KWhs generated would be and compared them to the maximum KWh savings would be from solar thermal hot water heater usage. These calculations assumed all of the residents of Pearl City had these systems installed and had a (conservatively high) 75% usage factor applied. For the month of December, for PV generation capacity installed such that the PV generation rate did not exceed residential loading during the peak PV hour, the number of KWhs generated for the day was calculated at 6,378.06 KWh and the estimated daily savings rate from the solar thermal systems was 2,143.13 KWh. For the month January, at the peak to residential loading installation value, the number if KWhs generated was calculated at 5,815.94 KWh with the savings rate from the solar thermal systems remaining at 2,143.13 KWh. It should be noted that these differences only widen for less conservative solar thermal usage estimates and for PV generation estimates that allow either storage or nonresidential loading to be taken into account.

VI. CONCLUSION

Many of the challenges posed by the neighborhood that was chosen could be considered unique to neighborhoods residing in military installations. Most neighborhood distribution systems are of much simpler

models, with groups of homes fed from dedicated substations and little more than a few street lights and a water pump on the transmission lines besides the residents. Because the methods outlined in this paper were able to create a working simulation for Pearl City, I am confident of their repeatability for the creation of modeling simulations for other neighborhoods.

While this simulation used Microsoft Excel, a strong case could be made that other off-the shelf programs such as Microsoft Access, Microsoft SharePoint, Apache Open Office, Bime, LibreOffice, and Numbers For Mac could have been used. It should be noted that the intention of this paper was not to show screen shots of Microsoft Excel formulas but rather to outline the processes and requirements necessary to create a neighborhood distribution simulation and to demonstrate the outcomes and design features of such a simulation. Replication of the methods and approaches outlined by this paper can lead to more expansive like-type loading profile databases and better data analysis. As demand from home owners and residential developers to integrate PV systems into their homes continues to rise, the demand for answers to the question of "what is the right amount of PV for me?" will continue to rise. Engineers seeking to solve the answers to these questions will require methods and tools to justify their responses, fueling demand for simulations such as the one produced for this paper.

VII. APPENDICES

[A] December KWh Consumption by Unit Type

[B] December Combined KWh Consumption

[C] Manual Load Selector Load Assumptions Table

[D] Final Design of the Simulation "Control Panel" tab

[E] Simplified For Scaling One-Line Power Flow Equivalent Schematic for Pearl City

[F] NAVFAC Hawaii DWG 821S

Average Daily KWh Consumption Statistics For Each Unit Type
For The Month Of December 2016

Average Daily Mean KWh Consumption For Each Unit Type

Average Daily Median KWh Consumption For Each Unit Type

Daily Average Mode KWh Consumption Per Hour For Each Unit Type

Daily Average Max KWh Consumption Per Hour For Each Unit Type

Daily Average Min KWh Consumption Per Hour For Each Unit Type

Daily Average Non-Zero Min KWh Consumption Per Hour For Each Unit Type

Legend: NPCP2JE1.5W948-98, NPCP2JE1.5W948-98_4, NPCP2JE1.5W948-99, NPCP2JE1W950-98, NPCP2JE1W950-99, NPCP3JE2W1200-99, NPCP3JE2W1200-99, NPCP3JE2W950-99, NPCP3SE2D1154-99, PC13C.1, PC13C.2, PC13C.3, PC13C.4, PC13C.5, PC14A.1, PC14A.2, PC14A.3, PC14A.4, PC14A.5, PC15A.1, PC15A.2, PC15A.3, PC15A.4, PC15A.5, PC15A.6, PC16A.1, PC16A.2, PC16A.3, PC16A.3H, PC16A.4, PC16A.5

UNIT TYPE NPCP2JE1.5W948-98 — NUMBER OF UNITS IN TYPE 50 — NUMBER OF BEDROOMS 2

	12AM	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
MEAN	0.91	0.77	0.68	0.66	0.67	0.75	0.80	0.80	0.98	1.07	1.02	1.08	1.13	1.23	1.28	1.34	1.43	1.45	1.49	1.59	1.51	1.42	1.30	1.08
MEDIAN	0.97	1.00	0.90	0.91	0.80	0.83	0.97	0.97	1.00	0.99	0.99	1.00	1.04	1.03	1.05	1.20	1.17	1.16	1.18	1.10	1.09	1.01	0.95	
MODE	0.85	0.92	0.69	0.73	0.58	0.58	0.58	0.58	0.88	0.73	0.81	0.96	1.00	0.92	0.92	1.08	1.08	1.04	1.23	1.23	1.19	1.04	1.01	0.97
MAX	2.79	2.16	1.90	1.83	1.96	3.02	2.80	2.74	3.42	3.85	3.83	3.88	3.76	4.23	3.96	3.91	4.13	4.14	4.52	4.88	4.63	4.62	4.50	3.57
MIN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NZ MIN	0.29	0.38	0.42	0.46	0.46	0.49	0.45	0.42	0.43	0.48	0.48	0.45	0.41	0.40	0.35	0.37	0.31	0.30	0.30	0.29	0.27	0.23	0.16	0.17

UNIT TYPE NPCP2JE1.5W948-98_4 — NUMBER OF UNITS IN TYPE 1 — NUMBER OF BEDROOMS 4
NOTES: ADDED A "_4" TO THE UNIT TYPE NUMBER TO DIFFERENTIATE THE LONE 4 BEDROOM UNIT

	12AM	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
MEAN	0.41	0.34	0.40	0.26	0.22	0.38	0.26	0.22	0.14	0.30	0.48	0.48	0.46	0.76	0.78	0.62	0.82	1.06	0.90	0.86	0.74	0.98	0.55	0.33
MEDIAN	0.41	0.34	0.40	0.26	0.22	0.38	0.26	0.22	0.14	0.30	0.48	0.48	0.46	0.76	0.78	0.62	0.82	1.06	0.90	0.86	0.74	0.98	0.55	0.33
MODE	0.41	0.34	0.40	0.26	0.22	0.38	0.26	0.22	0.14	0.30	0.48	0.48	0.46	0.76	0.78	0.62	0.82	1.06	0.90	0.86	0.74	0.98	0.55	0.33
MAX	0.41	0.34	0.40	0.26	0.22	0.38	0.26	0.22	0.14	0.30	0.48	0.48	0.46	0.76	0.78	0.62	0.82	1.06	0.90	0.86	0.74	0.98	0.55	0.33
MIN	0.41	0.34	0.40	0.26	0.22	0.38	0.26	0.22	0.14	0.30	0.48	0.48	0.46	0.76	0.78	0.62	0.82	1.06	0.90	0.86	0.74	0.98	0.55	0.33
NZ MIN	0.41	0.34	0.40	0.26	0.22	0.38	0.26	0.22	0.14	0.30	0.48	0.48	0.46	0.76	0.78	0.62	0.82	1.06	0.90	0.86	0.74	0.98	0.55	0.33

UNIT TYPE NPCP2JE1.5W948-99 — NUMBER OF UNITS IN TYPE 45 — NUMBER OF BEDROOMS 2

	12AM	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
MEAN	1.07	0.90	0.82	0.75	0.83	0.80	0.84	0.83	0.93	1.15	1.24	1.20	1.28	1.29	1.36	1.33	1.36	1.40	1.51	1.55	1.48	1.39	1.27	1.24
MEDIAN	0.96	1.00	0.93	0.93	0.91	0.94	0.94	0.93	0.98	1.01	1.00	0.99	1.08	1.07	1.19	1.10	1.12	1.10	1.17	1.18	1.16	1.04	0.97	0.98
MODE	0.91	0.92	0.81	0.81	0.69	0.77	0.77	0.85	0.81	0.92	0.96	0.96	1.04	1.12	1.19	1.12	1.15	1.23	1.15	1.31	1.19	1.01	0.93	1.04
MAX	3.65	2.90	2.24	2.21	2.75	2.47	2.93	2.86	2.98	3.70	3.94	3.61	3.79	3.50	3.41	3.47	3.39	3.37	4.14	4.40	4.17	3.94	4.14	4.02
MIN	0.00	-0.65	0.00	0.44	0.38	0.35	0.36	0.34	0.33	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.01	0.01	0.00	0.00	0.14	0.13
NZ MIN	0.32	0.48	0.44	0.38	0.35	0.36	0.34	0.33	0.34	0.36	0.35	0.33	0.31	0.31	0.31	0.27	0.28	0.29	0.28	0.32	0.25	0.22	0.14	0.13

UNIT TYPE NPCP2JE1W950-98 — NUMBER OF BEDROOMS 3

	12AM	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
MEAN	1.26	0.98	0.84	0.87	0.79	0.90	0.82	1.07	1.14	1.15	1.32	1.51	1.74	1.68	1.86	1.66	1.69	1.48	1.68	1.72	1.37	1.26	1.46	1.18
MEDIAN	1.26	0.98	0.84	0.87	0.79	0.90	0.82	1.07	1.14	1.15	1.32	1.51	1.74	1.68	1.86	1.66	1.69	1.48	1.68	1.72	1.37	1.26	1.46	1.18
MODE	1.26	0.98	0.84	0.87	0.79	0.90	0.82	1.07	1.14	1.15	1.32	1.51	1.74	1.68	1.86	1.66	1.69	1.48	1.68	1.72	1.37	1.26	1.46	1.18
MAX	1.12	0.88	0.71	0.78	0.70	0.78	0.69	0.92	0.94	0.99	1.05	1.24	1.42	1.30	1.43	1.32	1.33	1.15	1.34	1.37	1.14	1.00	1.21	0.88
MIN	0.83	0.70	0.64	0.62	0.57	0.66	0.63	0.81	0.82	0.72	0.90	1.10	1.17	1.20	1.33	1.15	1.18	1.04	1.16	1.19	0.89	0.87	0.96	0.80
NZ MIN	1.02	0.80	0.64	0.74	0.67	0.74	0.63	0.88	0.91	0.81	0.90	1.16	1.17	1.20	1.33	1.15	1.28	1.04	1.16	1.19	0.92	0.87	1.19	0.80

UNIT TYPE NPCP2JE1W950-99 — NUMBER OF UNITS IN TYPE 3 — NUMBER OF BEDROOMS 2

	12AM	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
MEAN	1.39	1.14	1.03	0.76	0.74	0.85	0.71	0.80	1.03	1.40	1.18	1.43	2.08	1.94	2.07	2.17	2.07	2.21	2.20	2.42	2.14	1.95	1.64	1.40
MEDIAN	1.30	1.04	0.99	0.72	0.79	0.77	0.56	0.67	0.95	1.41	1.09	1.33	1.83	1.78	1.79	1.93	1.95	1.95	2.22	2.23	2.06	1.77	1.58	1.25
MODE	1.30	1.04	0.99	0.72	0.79	0.77	0.56	0.67	0.95	1.41	1.09	1.33	1.83	1.78	1.79	1.93	1.95	1.95	2.22	2.23	2.06	1.77	1.58	1.25
MAX	1.69	1.50	1.34	1.15	1.11	1.16	1.13	1.21	1.69	1.98	1.73	2.01	2.79	2.52	2.71	2.71	2.79	2.58	2.87	2.55	2.38	2.06	1.90	
MIN	0.72	0.48	0.43	0.16	0.10	0.32	0.18	0.24	0.11	0.37	0.32	0.45	0.91	0.87	1.00	1.13	0.87	1.13	1.08	1.34	1.12	1.05	0.74	0.58
NZ MIN	0.78	0.94	0.85	0.89	0.86	0.85	0.97	0.83	1.05	1.05	0.93	0.90	1.23	1.03	1.13	1.23	1.21	1.21	1.08	1.37	1.12	1.12	0.81	0.64

UNIT TYPE NPCP3JE2W1200-98 — NUMBER OF UNITS IN TYPE 48 — NUMBER OF BEDROOMS 3

	12AM	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
MEAN	0.92	0.76	0.77	0.73	0.72	0.80	0.75	0.83	0.97	1.05	1.06	1.03	1.19	1.41	1.52	1.50	1.56	1.57	1.65	1.70	1.69	1.60	1.44	1.31
MEDIAN	0.97	0.91	0.91	0.90	0.66	0.82	0.84	0.91	0.96	1.00	1.00	1.00	1.21	1.39	1.26	1.36	1.38	1.34	1.39	1.35	1.17	1.02	0.97	0.96
MODE	0.77	0.46	0.58	0.46	0.15	0.35	0.50	0.65	0.65	0.73	1.00	0.92	1.23	1.42	1.23	1.58	1.27	1.27	1.31	1.27	1.12	1.12	1.00	0.92
MAX	2.57	2.30	2.27	2.40	2.62	3.08	2.51	2.80	3.30	4.02	3.66	3.74	3.81	4.13	4.29	4.13	4.29	4.75	4.50	5.10	4.48	4.39	3.96	3.66
MIN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NZ MIN	0.33	0.41	0.45	0.48	0.42	0.42	0.43	0.42	0.45	0.45	0.44	0.40	0.39	0.40	0.39	0.36	0.37	0.38	0.38	0.36	0.28	0.23	0.14	0.12

UNIT TYPE NPCP3JE2W1200-99 — NUMBER OF UNITS IN TYPE 39 — NUMBER OF BEDROOMS 3

	12AM	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
MEAN	1.15	0.90	0.84	0.80	0.83	0.90	0.95	0.98	1.00	1.07	1.25	1.36	1.48	1.74	1.75	1.84	1.85	1.86	1.78	1.91	1.97	1.74	1.64	1.37
MEDIAN	0.99	1.00	0.93	0.95	0.94	0.99	1.00	1.00	0.98	1.05	1.09	1.21	1.43	1.49	1.63	1.63	1.67	1.66	1.77	1.63	1.25	0.97	0.97	
MODE	0.96	0.77	0.69	0.77	0.69	0.85	0.92	0.85	0.92	0.96	1.04	1.27	1.38	1.58	1.58	1.42	1.46	1.69	1.62	1.58	1.19	1.05	0.98	
MAX	4.31	2.77	2.48	2.20	2.41	2.63	2.69	3.23	3.42	3.71	3.97	4.38	5.15	4.44	4.85	4.39	4.74	4.04	5.02	5.13	4.68	4.16	4.00	3.66
MIN	0.01	-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.07	0.04	0.04	0.06	0.06	0.05	0.03	0.00
NZ MIN	0.46	0.54	0.55	0.54	0.50	0.51	0.56	0.53	0.54	0.52	0.52	0.57	0.59	0.57	0.58	0.55	0.51	0.50	0.48	0.50	0.50	0.44	0.21	0.20

UNIT TYPE NPCP3JE2W950-99 — NUMBER OF UNITS IN TYPE 1 — NUMBER OF BEDROOMS 3

	12AM	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
MEAN	0.44	0.61	0.64	0.80	0.78	0.80	0.99	0.79	0.93	0.97	1.12	0.98	1.07	1.07	1.03	1.37	1.21	1.31	1.45	1.40	1.10	1.21	0.81	0.71
MEDIAN	0.44	0.61	0.64	0.80	0.78	0.80	0.99	0.79	0.93	0.97	1.12	0.98	1.07	1.07	1.03	1.37	1.21	1.31	1.45	1.40	1.10	1.21	0.81	0.71
MODE	0.44	0.61	0.64	0.80	0.78	0.80	0.99	0.79	0.93	0.97	1.12	0.98	1.07	1.07	1.03	1.37	1.21	1.31	1.45	1.40	1.10	1.21	0.81	0.71
MAX	0.44	0.61	0.64	0.80	0.78	0.80	0.99	0.79	0.93	0.97	1.12	0.98	1.07	1.07	1.03	1.37	1.21	1.31	1.45	1.40	1.10	1.21	0.81	0.71
MIN	0.44	0.61	0.64	0.80	0.78	0.80	0.99	0.79	0.93	0.97	1.12	0.98	1.07	1.07	1.03	1.37	1.21	1.31	1.45	1.40	1.10	1.21	0.81	0.71
NZ MIN	0.44	0.61	0.64	0.80	0.78	0.80	0.99	0.79	0.93	0.97	1.12	0.98	1.07	1.07	1.03	1.37	1.21	1.31	1.45	1.40	1.10	1.21	0.81	0.71

UNIT TYPE NPCP3SE2D1154-99 — NUMBER OF UNITS IN TYPE 8 — NUMBER OF BEDROOMS 3

	12AM	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
MEAN	0.90	0.85	0.73	0.68	0.73	0.84	0.81	0.90	0.93	1.13	1.39	1.43	1.42	1.48	1.60	1.60	1.75	1.67	1.73	1.60	1.73	1.60	1.49	1.22
MEDIAN	0.92	0.90	0.85	0.75	0.73	0.89	0.75	0.90	0.83	1.00	1.04	1.30	1.25	1.42	1.46	1.70	1.42	1.53	1.36	1.63	1.45	1.28	1.09	
MODE	0.79	0.69	0.65	0.62	0.42	0.69	0.50	0.54	0.69	0.92	0.81	1.12	1.09	1.23	1.42	1.58	1.27	1.23	1.42	1.05	1.35	1.08	0.93	
MAX	1.61	1.61	1.31	1.24	1.44	1.58	1.74	1.95	2.01	2.52	3.37	3.03	2.65	2.43	2.39	2.62	2.81	2.85	3.04	3.04	2.97	2.72	2.82	2.34
MIN	0.06	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.06	0.19	0.19	0.33	0.44	0.23	0.29	0.31	0.31	0.19	0.39	0.23	0.19	0.16	
NZ MIN	0.73	0.83	0.82	0.82	0.82	0.81	0.81	0.79	0.76	0.82	0.84	0.86	0.83	0.82	0.93	0.82	0.95	0.82	0.85	0.82	0.80	0.81	0.72	0.69

UNIT TYPE PC13C.1 — NUMBER OF UNITS IN TYPE 22 — NUMBER OF BEDROOMS 2

	12AM	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
MEAN	1.27	0.76	0.66	0.62	0.61	0.63	0.71	0.69	0.70	0.84	0.96	1.13	1.30	1.42	1.45	1.53	1.54	1.55	1.48	1.59	1.44	1.25	1.05	0.84
MEDIAN	1.00	0.64	0.58	0.43	0.51	0.41	0.56	0.72	0.72	0.92	0.85	0.98	1.12	1.35	1.40	1.36	1.37	1.33	1.23	1.34	1.13	1.02	0.95	0.72
MODE	1.00	0.46	0.38	0.27	0.27	0.35	0.42	0.42	0.58	0.62	0.73	0.88	0.96	1.23	1.31	1.35	1.35	1.51	1.24	1.27	0.92	0.94	1.04	0.62
MAX	5.00	2.42	2.03	1.97	1.84	2.05	2.58	2.07	2.29	2.52	2.68	2.77	3.23	3.39	3.42	3.48	3.74	3.52	3.68	4.16	3.52	3.29	3.13	2.51
MIN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00
NZ MIN	0.49	0.75	0.71	0.65	0.67	0.74	0.73	0.66	0.69	0.73	0.72	0.73	0.71	0.71	0.73	0.71	0.64	0.68	0.67	0.61	0.47	0.35	0.24	0.18

UNIT TYPE PC13C.2 — NUMBER OF UNITS IN TYPE 20 — NUMBER OF BEDROOMS 3

	12AM	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
MEAN	0.82	0.77	0.64	0.57	0.64	0.63	0.63	0.90	0.86	1.02	1.18	1.38	1.46	1.66	1.67	1.70	1.81	1.92	2.01	2.04	1.95	1.71	1.34	1.03
MEDIAN	0.76	0.69	0.52	0.43	0.45	0.63	0.82	0.78	0.98	1.02	1.09	1.17	1.51	1.31	1.54	1.47	1.62	1.77	1.86	1.65	1.53	1.11	0.95	
MODE	0.46	0.50	0.31	0.23	0.27	0.46	0.50	0.54	0.85	0.85	0.88	0.73	1.12	1.08	1.31	1.23	1.19	1.54	1.50	1.65	1.58	1.50	1.16	0.96
MAX	2.32	2.65	1.79	1.93	1.54	2.03	2.81	2.69	2.71	3.42	3.52	3.77	4.13	3.71	3.97	3.74	3.90	3.47	4.33	4.10	4.42	4.06	3.90	3.48
MIN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.09	0.11	0.18	0.11	0.52	0.28	0.27
NZ MIN	0.56	0.70	0.61	0.59	0.64	0.70	0.73	0.71	0.72	0.73	0.74	0.74	0.73	0.73	0.72	0.63	0.63	0.70	0.70	0.70	0.70	0.62	0.52	0.27

UNIT TYPE PC13C.3 — NUMBER OF UNITS IN TYPE 10 — NUMBER OF BEDROOMS 4

	12AM	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
MEAN	1.44	1.20	0.95	0.85	0.82	0.88	0.93	1.13	1.28	1.46	1.45	1.73	1.62	1.63	1.65	1.77	1.90	1.92	2.01	2.14	2.05	2.04	1.95	1.66
MEDIAN	1.17	1.10	0.96	0.91	0.88	0.91	0.94	1.02	1.12	1.33	1.23	1.44	1.43	1.40	1.68	1.81	1.80	1.76	1.99	1.88	1.91	1.74	1.46	
MODE	1.12	1.00	0.88	0.73	0.81	0.95	0.98	0.81	1.15	1.27	1.04	1.58	1.27	1.31	1.23	1.54	1.77	2.00	1.77	2.25	1.71	0.71	1.67	1.32
MAX	3.44	2.52	1.84	1.54	1.55	1.73	1.98	2.31	2.89	3.10	3.29	3.68	3.26	3.29	3.35	3.42	3.45	3.71	4.06	4.35	3.87	3.77	3.90	3.38
MIN	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.03	0.03	0.03	0.03	0.06	0.06	0.03	0.07	0.07	0.08	0.06	0.04	0.07	0.07
NZ MIN	0.73	0.84	0.79	0.77	0.79	0.79	0.79	0.79	0.76	0.79	0.87	0.87	0.87	0.82	0.82	0.82	0.78	0.76	0.76	0.77	0.77	0.77	0.77	0.71

UNIT TYPE PC13C.4 — NUMBER OF UNITS IN TYPE 1 — NUMBER OF BEDROOMS 4

	12AM	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
MEAN	1.59	1.50	1.29	1.23	1.29	1.27	1.31	2.12	2.19	2.42	3.19	3.27	3.58	4.25	4.67	4.63	4.56	4.15	4.00	3.89	3.59	2.89	2.09	2.03
MEDIAN	1.59	1.50	1.29	1.23	1.29	1.27	1.31	2.12	2.19	2.42	3.19	3.27	3.58	4.25	4.67	4.63	4.56	4.15	4.00	3.89	3.59	2.89	2.09	2.03
MODE	1.59	1.50	1.29	1.23	1.29	1.27	1.31	2.12	2.19	2.42	3.19	3.27	3.58	4.25	4.67	4.63	4.56	4.15	4.00	3.89	3.59	2.89	2.09	2.03
MAX	1.59	1.50	1.29	1.23	1.29	1.27	1.31	2.12	2.19	2.42	3.19	3.27	3.58	4.25	4.67	4.63	4.56	4.15	4.00	3.89	3.59	2.89	2.09	2.03
MIN	1.59	1.50	1.29	1.23	1.29	1.27	1.31	2.12	2.19	2.42	3.19	3.27	3.58	4.25	4.67	4.63	4.56	4.15	4.00	3.89	3.59	2.89	2.09	2.03
NZ MIN	1.59	1.50	1.29	1.23	1.29	1.27	1.31	2.12	2.19	2.42	3.19	3.27	3.58	4.25	4.67	4.63	4.56	4.15	4.00	3.89	3.59	2.89	2.09	2.03

UNIT TYPE PC13C.5 — NUMBER OF UNITS IN TYPE 26 — NUMBER OF BEDROOMS 4

	12AM	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
MEAN	0.96	0.84	0.73	0.69	0.71	0.73	0.79	0.85	0.93	1.06	1.27	1.52	1.68	1.85	1.94	2.10	2.04	1.98	2.03	1.95	1.71	1.66	1.44	1.17
MEDIAN	0.99	0.94	0.90	0.79	0.94	0.91	0.98	0.96	1.02	1.08	1.25	1.40	1.62	1.90	2.03	1.87	1.85	1.96	1.65	1.63	1.45	1.38	1.14	0.99
MODE	0.92	0.96	0.77	0.73	0.69	0.92	0.81	0.88	0.85	0.92	1.08	1.27	1.38	2.08	1.81	2.23	2.12	1.65	1.88	1.35	1.20	1.11	1.16	1.05
MAX	2.11	1.78	1.62	1.54	1.91	1.70	2.16	2.22	2.51	2.64	3.19	3.29	3.71	3.32	4.10	4.06	4.06	3.94	4.32	4.42	3.87	3.94	3.64	2.93
MIN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.04	0.10	0.05	0.10	0.10	0.07	0.10	0.03	0.62	0.57	0.01	0.03	
NZ MIN	0.54	0.68	0.61	0.62	0.59	0.55	0.59	0.57	0.54	0.56	0.61	0.63	0.60	0.58	0.61	0.62	0.63	0.63	0.59	0.64	0.62	0.57	0.39	0.38

UNIT TYPE PC14A.1 — NUMBER OF UNITS IN TYPE 1 — NUMBER OF BEDROOMS 3

	12AM	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
MEAN	0.49	0.35	0.23	0.08	0.31	0.15	0.15	0.19	0.12	0.27	0.31	0.23	0.12	0.54	0.54	0.69	0.65	0.50	0.42	0.27	0.35	0.46	0.19	0.23
MEDIAN	0.49	0.35	0.23	0.08	0.31	0.15	0.15	0.19	0.12	0.27	0.31	0.23	0.12	0.54	0.54	0.69	0.65	0.50	0.42	0.27	0.35	0.46	0.19	0.23
MODE	0.49	0.35	0.23	0.08	0.31	0.15	0.15	0.19	0.12	0.27	0.31	0.23	0.12	0.54	0.54	0.69	0.65	0.50	0.42	0.27	0.35	0.46	0.19	0.23
MAX	0.49	0.35	0.23	0.08	0.31	0.15	0.15	0.19	0.12	0.27	0.31	0.23	0.12	0.54	0.54	0.69	0.65	0.50	0.42	0.27	0.35	0.46	0.19	0.23
MIN	0.49	0.35	0.23	0.08	0.31	0.15	0.15	0.19	0.12	0.27	0.31	0.23	0.12	0.54	0.54	0.69	0.65	0.50	0.42	0.27	0.35	0.46	0.19	0.23
NZ MIN	0.49	0.35	0.23	0.08	0.31	0.15	0.15	0.19	0.12	0.27	0.31	0.23	0.12	0.54	0.54	0.69	0.65	0.50	0.42	0.27	0.35	0.46	0.19	0.23

UNIT TYPE PC14A.2 — NUMBER OF UNITS IN TYPE 1 — NUMBER OF BEDROOMS 3

	12AM	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
MEAN	0.73	0.55	0.60	0.21	0.38	0.96	1.29	1.75	2.23	1.35	0.88	0.65	1.08	0.63	0.98	0.70	1.04	1.35	2.39	3.39	3.10	2.18	1.30	0.68
MEDIAN	0.73	0.55	0.60	0.21	0.38	0.96	1.29	1.75	2.23	1.35	0.88	0.65	1.08	0.63	0.98	0.70	1.04	1.35	2.39	3.39	3.10	2.18	1.30	0.68
MODE	0.73	0.55	0.60	0.21	0.38	0.96	1.29	1.75	2.23	1.35	0.88	0.65	1.08	0.63	0.98	0.70	1.04	1.35	2.39	3.39	3.10	2.18	1.30	0.68
MAX	0.73	0.55	0.60	0.21	0.38	0.96	1.29	1.75	2.23	1.35	0.88	0.65	1.08	0.63	0.98	0.70	1.04	1.35	2.39	3.39	3.10	2.18	1.30	0.68
MIN	0.73	0.55	0.60	0.21	0.38	0.96	1.29	1.75	2.23	1.35	0.88	0.65	1.08	0.63	0.98	0.70	1.04	1.35	2.39	3.39	3.10	2.18	1.30	0.68
NZ MIN	0.73	0.55	0.60	0.21	0.38	0.96	1.29	1.75	2.23	1.35	0.88	0.65	1.08	0.63	0.98	0.70	1.04	1.35	2.39	3.39	3.10	2.18	1.30	0.68

UNIT TYPE PC14A.3 — NUMBER OF UNITS IN TYPE 1 — NUMBER OF BEDROOMS 3

	12AM	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
MEAN	1.70	1.58	1.67	1.73	1.50	1.42	2.12	2.85	1.96	1.79	1.52	1.92	2.31	2.62	2.75	2.87	2.88	2.38	2.54	3.55	3.28	3.05	2.17	1.98
MEDIAN	1.70	1.58	1.67	1.73	1.50	1.42	2.12	2.85	1.96	1.79	1.52	1.92	2.31	2.62	2.75	2.87	2.88	2.38	2.54	3.55	3.28	3.05	2.17	1.98
MODE	1.70	1.58	1.67	1.73	1.50	1.42	2.12	2.85	1.96	1.79	1.52	1.92	2.31	2.62	2.75	2.87	2.88	2.38	2.54	3.55	3.28	3.05	2.17	1.98
MAX	1.70	1.58	1.67	1.73	1.50	1.42	2.12	2.85	1.96	1.79	1.52	1.92	2.31	2.62	2.75	2.87	2.88	2.38	2.54	3.55	3.28	3.05	2.17	1.98
MIN	1.70	1.58	1.67	1.73	1.50	1.42	2.12	2.85	1.96	1.79	1.52	1.92	2.31	2.62	2.75	2.87	2.88	2.38	2.54	3.55	3.28	3.05	2.17	1.98
NZ MIN	1.70	1.58	1.67	1.73	1.50	1.42	2.12	2.85	1.96	1.79	1.52	1.92	2.31	2.62	2.75	2.87	2.88	2.38	2.54	3.55	3.28	3.05	2.17	1.98

UNIT TYPE: PC14A.4 — NUMBER OF UNITS IN TYPE: 1 — NUMBER OF BEDROOMS: 3 — NOTES:

	12AM	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
MEAN	0.06	0.10	0.10	0.18	0.14	0.18	0.22	0.22	0.15	0.18	0.01	0.12	0.05	0.16	0.09	0.16	0.24	0.16	0.26	0.11	0.17	0.06	0.18	0.10
MEDIAN	0.06	0.10	0.10	0.18	0.14	0.18	0.22	0.22	0.15	0.18	0.01	0.12	0.05	0.16	0.09	0.16	0.24	0.16	0.26	0.11	0.17	0.06	0.18	0.10
MODE	0.06	0.10	0.10	0.18	0.14	0.18	0.22	0.22	0.15	0.18	0.01	0.12	0.05	0.16	0.09	0.16	0.24	0.16	0.26	0.11	0.17	0.06	0.18	0.10
MAX	0.06	0.10	0.10	0.18	0.14	0.18	0.22	0.22	0.15	0.18	0.01	0.12	0.05	0.16	0.09	0.16	0.24	0.16	0.26	0.11	0.17	0.06	0.18	0.10
MIN	0.06	0.10	0.10	0.18	0.14	0.18	0.22	0.22	0.15	0.18	0.01	0.12	0.05	0.16	0.09	0.16	0.24	0.16	0.26	0.11	0.17	0.06	0.18	0.10
NZ MIN	0.06	0.10	0.10	0.18	0.14	0.18	0.22	0.22	0.15	0.18	0.01	0.12	0.05	0.16	0.09	0.16	0.24	0.16	0.26	0.11	0.17	0.06	0.18	0.10

UNIT TYPE: PC14A.5 — NUMBER OF UNITS IN TYPE: 1 — NUMBER OF BEDROOMS: 3 — NOTES:

	12AM	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
MEAN	0.67	0.60	0.41	0.33	0.23	0.39	0.42	0.54	2.14	3.14	2.35	1.85	1.42	2.08	2.55	2.20	2.01	2.35	2.47	2.51	2.44	1.62	1.66	0.99
MEDIAN	0.67	0.60	0.41	0.33	0.23	0.39	0.42	0.54	2.14	3.14	2.35	1.85	1.42	2.08	2.55	2.20	2.01	2.35	2.47	2.51	2.44	1.62	1.66	0.99
MODE	0.67	0.60	0.41	0.33	0.23	0.39	0.42	0.54	2.14	3.14	2.35	1.85	1.42	2.08	2.55	2.20	2.01	2.35	2.47	2.51	2.44	1.62	1.66	0.99
MAX	0.67	0.60	0.41	0.33	0.23	0.39	0.42	0.54	2.14	3.14	2.35	1.85	1.42	2.08	2.55	2.20	2.01	2.35	2.47	2.51	2.44	1.62	1.66	0.99
MIN	0.67	0.60	0.41	0.33	0.23	0.39	0.42	0.54	2.14	3.14	2.35	1.85	1.42	2.08	2.55	2.20	2.01	2.35	2.47	2.51	2.44	1.62	1.66	0.99
NZ MIN	0.67	0.60	0.41	0.33	0.23	0.39	0.42	0.54	2.14	3.14	2.35	1.85	1.42	2.08	2.55	2.20	2.01	2.35	2.47	2.51	2.44	1.62	1.66	0.99

UNIT TYPE: PC15A.1 — NUMBER OF UNITS IN TYPE: 73 — NUMBER OF BEDROOMS: 2 — NOTES:

	12AM	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
MEAN	1.15	1.05	0.93	0.93	0.93	0.98	1.00	0.98	1.10	1.20	1.31	1.42	1.45	1.51	1.58	1.60	1.62	1.68	1.82	1.78	1.76	1.62	1.44	1.30
MEDIAN	0.99	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.04	1.12	1.26	1.29	1.34	1.32	1.29	1.54	1.59	1.64	1.48	1.06	0.97
MODE	0.96	1.00	1.00	1.00	1.00	1.00	0.96	0.96	1.00	1.00	1.00	1.00	1.04	1.15	1.27	1.35	1.35	1.19	1.42	1.46	1.58	1.38	1.20	1.01
MAX	3.57	3.17	3.17	3.21	3.39	3.55	3.77	3.69	4.14	4.52	4.63	4.89	4.82	4.71	5.10	4.71	5.11	5.60	5.37	4.97	4.69	4.62	4.46	
MIN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NZ MIN	0.33	0.55	0.52	0.52	0.48	0.47	0.48	0.52	0.49	0.55	0.62	0.61	0.56	0.51	0.44	0.43	0.44	0.43	0.37	0.37	0.22	0.19	0.08	0.10

UNIT TYPE: PC15A.2 — NUMBER OF UNITS IN TYPE: 4 — NUMBER OF BEDROOMS: 2 — NOTES:

	12AM	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
MEAN	0.61	0.56	0.50	0.50	0.70	0.62	0.59	0.59	0.49	0.63	0.71	0.87	0.98	1.03	1.12	1.17	1.21	1.36	1.49	1.44	1.34	1.15	0.81	0.58
MEDIAN	0.49	0.50	0.45	0.46	0.59	0.54	0.58	0.58	0.44	0.54	0.72	0.71	0.80	0.88	1.04	1.10	1.03	1.18	1.39	1.29	1.19	0.93	0.72	0.55
MODE	0.35	0.16	0.23	0.31	0.31	0.26	0.58	0.48	0.38	0.38	0.41	0.40	0.56	0.57	0.73	0.89	0.83	1.02	1.40	1.25	1.22	0.75	0.59	0.43
MAX	1.17	1.05	0.89	0.88	1.29	1.15	0.93	1.00	0.90	1.19	1.16	1.68	1.90	1.85	1.97	1.97	2.16	2.29	2.34	2.40	2.42	2.17	1.42	0.95
MIN	0.04	0.00	0.03	0.00	0.03	0.03	0.06	0.00	0.00	0.00	0.00	0.03	0.03	0.13	0.06	0.10	0.16	0.28	0.30	0.26	0.05	0.13	0.04	0.05
NZ MIN	0.75	0.81	0.82	0.82	0.90	0.94	0.77	0.82	0.81	0.81	0.85	0.90	0.98	0.94	1.13	0.95	1.05	0.92	0.94	0.75	0.77	0.86	0.82	0.56

UNIT TYPE: PC15A.3 — NUMBER OF UNITS IN TYPE: 58 — NUMBER OF BEDROOMS: 3 — NOTES:

	12AM	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
MEAN	1.20	1.07	0.98	0.96	1.00	1.08	1.14	1.19	1.15	1.24	1.38	1.52	1.57	1.63	1.63	1.67	1.69	1.83	1.85	2.00	1.96	1.74	1.51	1.31
MEDIAN	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.18	1.29	1.41	1.51	1.46	1.50	1.67	1.80	1.88	1.69	1.63	1.16	0.97
MODE	1.00	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00	1.04	1.12	1.23	1.31	1.31	1.50	1.35	1.46	1.35	1.58	1.38	1.50	1.19	1.06
MAX	3.33	2.60	2.84	3.09	3.32	4.14	4.06	4.48	4.09	4.25	4.54	4.71	4.61	5.00	4.74	4.83	5.13	5.32	5.51	5.88	5.67	5.29	4.64	4.52
MIN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NZ MIN	0.47	0.51	0.44	0.49	0.54	0.48	0.45	0.52	0.49	0.49	0.51	0.55	0.51	0.45	0.47	0.44	0.47	0.43	0.42	0.39	0.33	0.25	0.17	0.16

UNIT TYPE: PC15A.4 — NUMBER OF UNITS IN TYPE: 4 — NUMBER OF BEDROOMS: 3 — NOTES:

	12AM	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
MEAN	1.43	1.58	1.42	1.36	1.18	1.12	0.98	0.82	0.84	0.88	1.05	1.19	1.47	1.75	1.85	1.91	1.85	1.97	1.91	1.92	2.00	1.86	1.88	1.74
MEDIAN	1.32	1.39	1.22	1.26	0.99	0.92	0.87	0.78	0.79	0.85	0.96	1.17	1.46	1.70	1.78	1.94	1.84	2.01	1.94	1.85	1.95	1.79	1.81	1.68
MODE	1.32	1.42	1.04	1.22	0.98	0.89	0.77	0.80	0.77	0.88	1.00	1.23	1.65	1.92	1.79	2.00	1.92	2.05	2.17	2.03	2.05	1.81	1.75	1.78
MAX	2.45	2.71	2.68	2.37	2.08	2.13	1.68	1.35	1.29	1.39	1.77	1.90	2.32	2.65	2.87	2.84	2.68	2.68	2.71	3.06	3.02	2.92	2.98	2.79
MIN	0.15	0.26	0.03	0.06	0.21	0.06	0.15	0.10	0.19	0.15	0.13	0.13	0.16	0.35	0.34	0.32	0.44	0.56	0.45	0.27	0.41	0.33	0.29	0.23
NZ MIN	1.02	0.91	1.11	1.05	0.94	0.97	0.85	0.89	0.81	0.89	1.03	0.97	1.23	1.16	1.10	1.11	1.03	1.08	1.06	1.02	0.86	1.05	0.97	0.97

UNIT TYPE: PC15A.5 — NUMBER OF UNITS IN TYPE: 21 — NUMBER OF BEDROOMS: 4 — NOTES:

	12AM	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
MEAN	1.65	1.49	1.42	1.40	1.51	1.68	1.90	1.82	1.64	1.72	1.86	2.07	2.23	2.38	2.55	2.48	2.61	2.65	2.77	2.96	2.81	2.55	2.35	1.95
MEDIAN	1.55	1.34	1.07	1.11	1.16	1.36	1.47	1.49	1.29	1.45	1.51	1.86	2.00	2.14	2.35	2.23	2.38	2.46	2.45	2.56	2.25	2.25	1.98	1.62
MODE	1.42	1.31	1.08	1.19	1.19	1.15	1.19	1.27	1.23	1.38	1.35	1.62	1.85	2.23	2.04	2.27	2.42	2.23	2.15	2.50	2.35	2.29	1.83	1.28
MAX	3.29	2.99	3.55	3.54	4.00	4.36	5.43	4.86	4.44	4.51	4.78	5.22	5.00	4.90	5.08	5.16	5.31	5.93	5.93	6.70	6.28	5.83	5.96	5.24
MIN	0.03	0.02	0.02	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.03	0.10	0.27	0.36	0.29	0.35	0.22	0.13	0.11	0.05	0.07	0.00	0.10
NZ MIN	0.60	0.69	0.63	0.64	0.61	0.62	0.70	0.69	0.68	0.69	0.66	0.66	0.70	0.71	0.73	0.85	0.79	0.80	0.79	0.79	0.72	0.66	0.48	0.41

UNIT TYPE: PC15A.6 — NUMBER OF UNITS IN TYPE: 2 — NUMBER OF BEDROOMS: 4 — NOTES:

	12AM	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
MEAN	1.14	1.03	0.83	0.81	0.73	1.55	1.57	1.18	1.11	1.16	1.05	1.08	1.56	1.76	1.79	2.22	2.50	2.53	2.47	2.70	2.24	1.81	1.57	1.08
MEDIAN	1.14	1.03	0.83	0.81	0.73	1.55	1.57	1.18	1.11	1.16	1.05	1.08	1.56	1.76	1.79	2.22	2.50	2.53	2.47	2.70	2.24	1.81	1.57	1.08
MODE	1.14	1.03	0.83	0.81	0.73	1.55	1.57	1.18	1.11	1.16	1.05	1.08	1.56	1.76	1.79	2.22	2.50	2.53	2.47	2.70	2.24	1.81	1.57	1.08
MAX	1.56	1.44	1.21	1.30	1.36	1.83	1.64	1.36	1.30	1.52	1.11	1.65	2.35	2.74	2.74	2.65	2.84	2.42	2.04	2.95	2.04	1.95	1.39	
MIN	0.72	0.62	0.46	0.48	0.33	0.77	0.99	0.61	0.56	0.42	0.65	0.58	0.90	1.05	0.95	1.36	1.45	1.51	1.49	1.49	1.34	1.00	0.69	0.42
NZ MIN	0.93	0.89	0.82	0.81	0.84	1.29	1.10	0.96	0.94	0.94	0.70	0.86	1.16	1.11	0.98	1.36	1.48	1.51	1.49	1.69	1.34	1.04	1.06	0.86

UNIT TYPE: PC16A.1 — NUMBER OF UNITS IN TYPE: 121 — NUMBER OF BEDROOMS: 3 — NOTES:

	12AM	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
MEAN	1.32	0.91	0.83	0.78	0.77	0.83	0.91	0.92	0.97	1.15	1.22	1.28	1.35	1.37	1.43	1.48	1.54	1.58	1.70	1.70	1.55	1.44	1.25	1.12
MEDIAN	0.98	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.04	1.12	1.17	1.19	1.28	1.35	1.48	1.49	1.17	0.97	0.97	0.97
MODE	0.98	0.96	1.00	0.96	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.04	1.12	1.15	1.23	1.31	1.35	1.46	1.27	1.12	1.00	1.00	0.96
MAX	45.98	5.29	4.98	4.88	5.02	6.12	6.46	6.56	7.02	7.20	7.15	7.09	6.44	6.49	6.51	6.87	6.39	6.94	7.04	6.02	5.89	5.92	5.50	5.41
MIN	-9.24	-2.71	-2.35	-2.35	-2.35	-2.63	-2.63	-2.63	-2.63	-1.03	-1.09	-2.58	-2.58	-2.58	-2.58	-2.25	-2.25	-2.25	-2.24	-2.24	-2.25	-2.25	-2.25	-2.25
NZ MIN	0.29	0.37	0.39	0.36	0.40	0.40	0.40	0.42	0.40	0.41	0.40	0.42	0.36	0.35	0.33	0.33	0.30	0.30	0.30	0.28	0.19	0.10	0.08	0.08

UNIT TYPE: PC16A.2 — NUMBER OF UNITS IN TYPE: 54 — NUMBER OF BEDROOMS: 3 — NOTES:

	12AM	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
MEAN	1.01	0.85	0.74	0.72	0.73	0.74	0.81	0.80	1.02	1.28	1.38	1.33	1.45	1.47	1.54	1.60	1.63	1.62	1.71	1.72	1.63	1.56	1.32	1.16
MEDIAN	0.98	1.00	0.89	0.89	0.96	0.92	0.94	0.89	1.00	1.01	1.01	1.00	1.17	1.25	1.41	1.47	1.54	1.35	1.66	1.63	1.35	1.13	0.97	0.97
MODE	0.88	1.00	0.85	0.81	0.85	0.85	0.81	0.81	0.96	1.00	1.00	1.00	1.12	1.23	1.35	1.46	1.42	1.23	1.54	1.38	1.35	1.09	1.01	0.97
MAX	5.12	2.96	2.80	2.66	2.46	2.88	3.79	4.20	4.83	5.02	5.08	4.89	5.21	4.82	4.76	4.89	4.57	5.11	5.05	5.27	5.37	5.79	5.01	4.73
MIN	-0.58	-0.39	0.00	0.00	0.00	-0.01	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21
NZ MIN	0.38	0.52	0.51	0.49	0.52	0.46	0.46	0.45	0.52	0.51	0.48	0.45	0.44	0.46	0.48	0.51	0.45	0.39	0.41	0.46	0.33	0.22	0.14	0.11

UNIT TYPE: PC16A.3 — NUMBER OF UNITS IN TYPE: 2 — NUMBER OF BEDROOMS: 3 — NOTES:

	12AM	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
MEAN	0.84	0.29	0.37	0.58	0.63	0.46	0.94	0.87	1.08	1.22	0.80	0.69	0.75	0.66	0.71	0.93	0.76	0.83	0.97	0.73	0.87	0.73	0.57	0.83
MEDIAN	0.84	0.29	0.37	0.58	0.63	0.46	0.94	0.87	1.08	1.22	0.80	0.69	0.75	0.66	0.71	0.93	0.76	0.83	0.97	0.73	0.87	0.73	0.57	0.83
MODE	0.84	0.29	0.37	0.58	0.63	0.46	0.94	0.87	1.08	1.22	0.80	0.69	0.75	0.66	0.71	0.93	0.76	0.83	0.97	0.73	0.87	0.73	0.57	0.83
MAX	1.19	0.49	0.58	0.77	0.87	0.71	1.42	1.16	1.26	1.52	1.02	0.94	0.88	1.05	1.17	1.17	0.90	1.04	0.88	0.73	0.90	0.34	0.23	0.39
MIN	0.23	0.00	0.03	0.19	0.19	0.06	0.16	0.29	0.55	0.53	0.32	0.23	0.42	0.23	0.23	0.34	0.21	0.24	0.47	0.33	0.42	0.34	0.23	0.39
NZ MIN	0.94	0.49	0.58	0.74	0.74	0.68	1.26	1.10	0.84	1.11	0.92	0.84	0.77	0.73	0.84	0.89	0.92	1.00	0.89	0.72	0.78	0.67	0.67	0.88

UNIT TYPE: PC16A.3H — NUMBER OF UNITS IN TYPE: 9 — NUMBER OF BEDROOMS: 3 — NOTES:

	12AM	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
MEAN	3.41	0.98	0.91	0.69	0.85	0.95	0.90	0.95	0.91	1.13	1.20	1.56	1.39	1.49	1.50	1.54	1.49	1.47	1.59	1.60	1.38	1.37	1.27	1.22
MEDIAN	0.85	0.89	0.89	0.65	0.83	0.95	0.87	0.93	0.86	0.95	1.07	1.25	1.30	1.49	1.40	1.51	1.34	1.35	1.46	1.18	1.07	1.12	1.07	0.99
MODE	0.71	0.69	0.77	0.70	0.58	0.92	0.68	0.93	0.77	0.96	1.04	1.23	1.23	1.50	1.69	1.73	1.54	1.54	1.54	1.50	1.18	1.13	1.07	1.01
MAX	20.31	2.65	2.25	1.68	2.44	2.49	2.25	2.45	2.33	2.74	2.87	3.75	3.19	3.22	3.36	3.23	3.38	3.26	3.84	4.00	3.58	3.58	3.32	3.52
MIN	-0.67	-0.22	-0.22	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	-0.22	-0.16	-0.12	-0.73	-0.73	-0.66	-0.69	-0.69	-0.71	-0.71	-0.72	-0.75	-0.79	-0.58	-0.65
NZ MIN	0.68	0.72	0.76	0.79	0.82	0.79	0.73	0.73	0.76	0.70	0.72	0.68	0.53	0.03	0.23	-0.05	0.17	0.15	-0.10	-0.06	0.40	-0.08	0.46	0.43

UNIT TYPE: PC16A.4 — NUMBER OF UNITS IN TYPE: 5 — NUMBER OF BEDROOMS: 4 — NOTES:

	12AM	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
MEAN	1.24	1.12	1.04	0.91	1.62	1.35	1.13	1.41	1.52	1.62	1.62	1.79	1.88	2.18	2.19	2.21	2.30	2.27	2.37	2.41	2.21	1.84	1.65	1.40
MEDIAN	1.20	0.94	1.04	0.96	1.49	1.11	1.06	1.30	1.41	1.62	1.67	1.73	1.81	2.13	2.15	2.23	2.14	2.35	2.40	2.16	1.86	1.58	1.41	
MODE	1.20	0.94	1.04	0.95	1.40	1.04	1.04	1.26	1.35	1.55	1.65	1.62	1.61	1.74	1.92	2.07	2.09	2.11	2.33	2.34	2.06	1.79	1.52	1.44
MAX	1.67	1.65	1.27	1.24	2.24	2.15	1.45	2.02	2.21	2.12	1.89	2.26	2.45	2.95	2.87	2.86	3.03	3.03	3.10	3.06	2.87	2.31	2.28	1.82
MIN	0.47	0.44	0.45	0.21	0.73	0.50	0.50	0.52	0.48	0.66	0.79	0.90	0.84	0.85	0.91	0.93	0.92	0.89	0.94	1.00	0.98	0.75	0.62	0.52
NZ MIN	0.81	0.83	0.81	0.79	0.85	0.82	0.82	0.79	0.83	0.89	0.85	0.90	1.03	0.89	1.04	0.96	0.99	0.95	1.00	1.05	0.93	0.77	0.69	

UNIT TYPE: PC16A.5 — NUMBER OF UNITS IN TYPE: 1 — NUMBER OF BEDROOMS: 4 — NOTES:

	12AM	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
MEAN	0.17	0.29	0.12	0.11	0.16	0.34	0.29	0.13	0.08	0.27	0.22	0.21	0.27	0.37	0.31	0.42	0.85	0.71	0.43	0.86	0.34	0.25	0.17	0.22
MEDIAN	0.17	0.29	0.12	0.11	0.16	0.34	0.29	0.13	0.08	0.27	0.22	0.21	0.27	0.37	0.31	0.42	0.85	0.71	0.43	0.86	0.34	0.25	0.17	0.22
MODE	0.17	0.29	0.12	0.11	0.16	0.34	0.29	0.13	0.08	0.27	0.22	0.21	0.27	0.37	0.31	0.42	0.85	0.71	0.43	0.86	0.34	0.25	0.17	0.22
MAX	0.15	0.22	0.09	0.08	0.11	0.23	0.21	0.11	0.06	0.19	0.16	0.15	0.22	0.28	0.21	0.31	0.56	0.53	0.30	0.61	0.24	0.18	0.11	0.15
MIN	0.09	0.18	0.08	0.07	0.11	0.23	0.20	0.07	0.05	0.18	0.15	0.14	0.18	0.25	0.21	0.28	0.56	0.46	0.30	0.61	0.24	0.18	0.11	0.14
NZ MIN	0.15	0.22	0.09	0.08	0.11	0.23	0.21	0.11	0.06	0.19	0.16	0.15	0.19	0.25	0.21	0.31	0.56	0.53	0.30	0.61	0.24	0.18	0.11	0.15

Combined Average Hourly KWh Demand, Daily KWh Consumption, Solar Irradiance, and Temperature For The Month Of December 2016

Average Total Hourly KWh Demand for the Month of December

Solar Irradiance By Hour In Pearl City For The Month of December

Total KWh Demand Per Day for the Month of December

No reports for December 21-25

Daily High and Low Temperatures For Honolulu
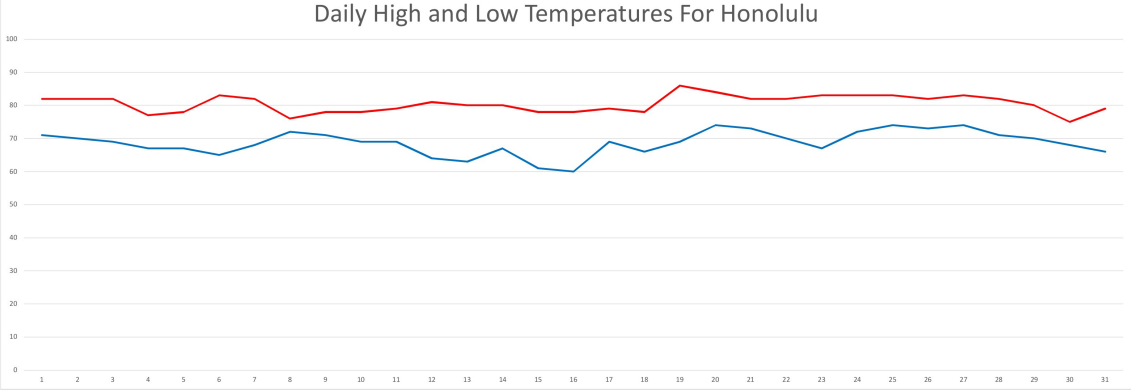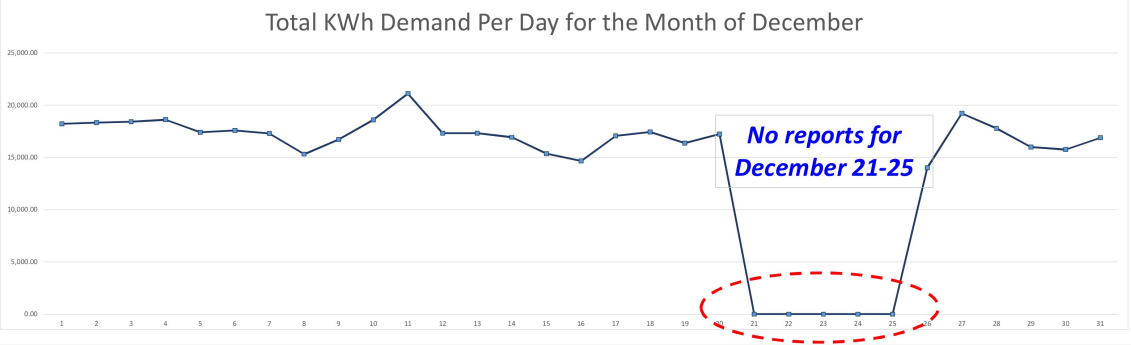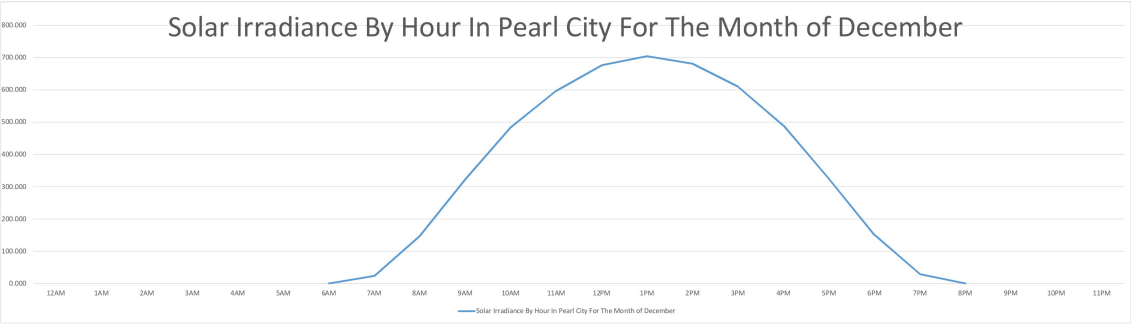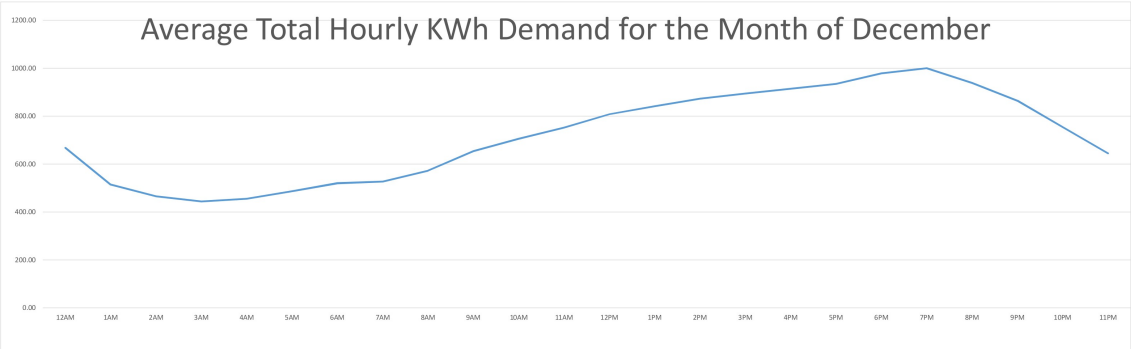
APPENDIX C

		Maximum KVA	Multiplier For	Nominal Running	Notes
1	DRYER	5	0.5	2.5	The dryer will be at full load only upon starting up with a full capacity of clothes. After startup, the heating elements are only kicking on
3					to maintain the temperature and the motor is at running amperage. A multiplier of 0.5 applied to the full load rating is conservatively
5	WASHER	1.5	0.75	1.125	The electrical loading of a washing machine is primarily a motor that starts and reverses frequently throughout the course of a wash
7	L & R LAUNDRY	0.72	1	0.72	
9	R- KITCHEN	0.72	1	0.72	
11	R- KITCHEN	0.72	1	0.72	
13	R - DISPOSAL	1.59	0.5	0.79	The garbage disposal and the dishwasher are supplied as 120V loads from each line in a 2 pole circuit breaker. The full load rating of the
15	R - DISHWASHER	1.08	0.75	0.81	garbage disposal is 1.587 KVA and the full load rating of the dishwasher is 1.08 KVA. Since spray jets and heating elements within a
17	R - MICRO	1.8	0.75	1.35	Since the defalt setting of most microwaves is the "high" setting and microwaves have to be manually set to lower percentages a value
19	R - RANGE	14.2	0.25	3.55	The range is at full load only when the oven is heating up to "Broil" and all surface burners are heating up to their high settings. Since
21					the burners only kick-on to maintain temperature once they have achieved the setting of their thermostats and it is most likely that only
23	L & R L/VENT/PWDR	0.72	1	0.72	
25	R - SECURITY	0.04	1	0.04	
27	L & R PORCH & LANAI	0.72	1	0.72	
29	SMOKE DETECTORS	0.04	1	0.04	
31	L & R STAIRS/HALL	0.72	1	0.72	
33	L & R BATH	0.72	1	0.72	
35	FCU	0.943	0.5	0.4715	Value for the Fan Coil Unit (FCU) added to the "Air Conditioner" total in cells C51:E51. A value of 0.5 was assigned to the running
37					multiplier on the assumption that the fan draws maximum power only upon initial start up with a clogged filter.
39					SPARE
2	WATER HEATER	4.5	0.95	4.275	Because water heater elements are essentially "binary systems" in that they are designed to come "on" and then come "off" at their
4					rated value, a high value of 0.95 was chosen for the running KVA multiplier with a reduction only to represent the fact that the heater
6	ACCU	4.19	0.5	2.095	Value for the Air Cooled Condensing Unit (ACCU) added to the "Air Conditioner" total in cells C51:E51. A value of 0.5 was assigned to the
8					running multiplier on the assumption that the compressor draws maximum power only when the freon heat sink is at maximum rated
10	R - MEDIA CAB	0.72	1	0.72	
12	L & R GARAGE	0.72	1	0.72	
14	L & R GARAGE	0.72	1	0.72	
16	R - REFER	0.75	0.25	0.1875	Since refrigerator doors are generally shut and refrigerator compressors tend to run only to maintain internal temperature low against
18	L & R KITCHEN DINING	0.72	1	0.72	
20	R - DINING	0.72	1	0.72	
22	SOLAR PUMP	0.07	1	0.07	
24	R - LIVING ROOM	0.72	1	0.72	
26	R - MASTER BR	0.72	1	0.72	
28	L & R MASTER BR	0.72	1	0.72	
30	L & R MASTER BATH	0.72	1	0.72	
32	L & R BED 2	0.72	1	0.72	
34	L & R BED 3	0.72	1	0.72	
36					SPARE
38					SPARE
40					SPARE

Load and PV Generation Capacity Control Panel

Monthly Profile Selector	January		Daily Residential Load (KWh)	17215.03		Substation KVA Rating	50000.00

						Daily PV Generation (KWh)	7063.05
						Peak PV From Residents (KW)	689.22
Rated Pri Voltage	11500.00		Peak PV Residential Load	868.15		Total Load KVA Rating	17843.00	Peak PV from Solar Farm (KW)	364.97
Rated Sec Voltage	240.00		Net Residential Load At Peak PV	-186.04		Residential Load KVA Rating	9230.50	PV Daily "Over" Generation	550.77
Actual Pri Voltage At Peak PV	11518.21		Peak PV Nonresidential Load	1027.74		Nonresidential Load KVA Rating	8612.50	Savings From Solar Thermal (KWh)	2143.13
						Solar Thermal Usage Factor	0.75

	12AM	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
PV Generation Rate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	57.79	321.76	612.33	851.27	1000.52	1054.19	1012.71	891.88	699.91	421.59	138.00	1.10	0.00	0.00	0.00	0.00
Residential Hourly Load Profile	646.71	523.93	480.86	451.36	453.78	499.46	528.90	536.00	548.83	614.74	690.97	766.57	834.00	868.15	899.20	940.91	981.19	985.22	986.44	976.45	909.51	812.84	701.95	577.06
Residential Load Profile With PV (No Storage)	646.71	523.93	480.86	451.36	453.78	499.46	528.90	536.00	491.03	292.99	78.64	-84.70	-166.51	-186.04	-113.52	49.02	281.28	563.62	848.44	975.35	909.51	812.84	701.95	577.06
Residential Load Profile With Balanced Storage	646.71	523.93	480.86	451.36	453.78	499.46	528.90	536.00	491.03	292.99	78.64	0.00	0.00	0.00	49.02	281.28	534.64	819.45	946.37	880.53	783.85	672.96	548.08	
Nonresidential Load	457.69	446.64	457.34	448.53	458.08	563.44	744.52	859.11	949.35	953.54	976.00	983.01	1013.82	1027.74	1097.81	1072.83	1019.72	935.18	873.62	738.67	571.72	517.48	509.60	507.98
Combined PV, Residential, and Nonresidential Load	1104.41	970.56	938.20	899.88	911.86	1062.90	1273.42	1395.11	1440.39	1246.52	1054.64	898.31	847.31	841.70	984.30	1121.86	1301.00	1498.80	1722.06	1714.03	1481.23	1330.32	1211.55	1085.05
Combined With Storage	1104.41	970.56	938.20	899.88	911.86	1062.90	1273.42	1395.11	1440.39	1246.52	1054.64	983.01	1013.82	1027.74	1097.81	1121.86	1301.00	1469.81	1693.07	1685.04	1452.24	1301.33	1182.56	1056.06

Like Type Global Assignment

Unit Type	Load Profile	Load Assignment	PV Assignment	Residents With Solar Thermal
NPCP2JE1.5W948-98	Mean	1.10	0.00	50
NPCP2JE1.5W948-98_4	Mean	0.62	0.00	1
NPCP2JE1.5W948-99	Mean	1.21	3.00	45
NPCP2JE1W950-98	Mean	1.48	1.00	2
NPCP2JE1W950-99	Mean	1.63	2.50	3
NPCP3JE2W1200-98	Mean	1.31	3.00	48
NPCP3JE2W1200-99	Mean	1.61	0.00	39
NPCP3JE2W950-99	Mean	1.19	0.00	1
NPCP3SE2D1154-99	Mean	1.34	4.00	8
PC13C.1	Mean	1.17	1.50	22
PC13C.2	Mean	1.36	0.00	20
PC13C.3	Mean	1.39	1.50	10
PC13C.4	Mean	4.47	0.00	1
PC13C.5	Mean	1.85	1.50	26
PC14A.1	Mean	0.85	0.00	1
PC14A.2	Mean	2.24	1.50	1
PC14A.3	Mean	2.18	1.50	1
PC14A.4	Mean	0.14	1.50	1
PC14A.5	Mean	1.52	0.00	1
PC15A.1	Mean	1.32	1.50	73
PC15A.2	Mean	1.24	1.50	4
PC15A.3	Mean	1.41	1.50	58
PC15A.4	Mean	1.35	1.50	4
PC15A.5	Mean	2.12	1.50	21
PC15A.6	Mean	1.71	1.50	2
PC16A.1	Mean	1.28	1.50	121
PC16A.2	Mean	1.33	1.50	54
PC16A.3	Mean	0.46	1.50	2
PC16A.3H	Mean	1.20	1.50	9
PC16A.4	Mean	1.97	1.50	5
PC16A.5	Mean	0.44	1.50	1

Nonresidential Load	KVA Rating	Load Assignment	PV Assignment
Solar Farm Output	1000	0.00	500.00
	4225	507.00	0.00
	2500	300.00	0.00
	750	90.00	0.00
	300	36.00	0.00
	300	36.00	0.00
	75	9.00	0.00
	75	9.00	0.00
	75	9.00	0.00
	50	6.00	0.00
	50	6.00	0.00
	45	5.40	0.00
	37.5	4.50	0.00
	25	3.00	0.00
	25	3.00	0.00
	15	1.80	0.00
	15	1.80	0.00
	15	1.80	0.00
	15	1.80	0.00
	10	1.20	0.00
	10	1.20	0.00

Residential Daily Loading vs PV Profile

Total Substation Loading vs PV Profile

Transformer Loading and Voltage

XFMR	KVA	KW_NET	V_PRI	V_SEC	XFMR	KVA	KW_NET	V_PRI	V_SEC	XFMR	KVA	KW_NET	V_PRI	V_SEC
9001	10	1.20	11500.00	238.20	9038	39	-1.18	11463.52	239.24	9075	50	1.42	11500.00	239.11
9002	15	1.80	11500.00	238.20	9039	25	3.00	11500.00	238.20	9076	38	1.02	11500.00	239.28
9003	15	1.80	11500.00	238.20	9040	10	0.00	11456.05	239.08	9077	38	0.99	11500.00	238.82
9004	50	6.00	11500.00	238.20	9041	50	-0.71	11429.83	238.54	9078	50	2.07	11500.00	238.20
9005	250	-0.88	11466.20	239.29	9042	50	-1.13	11434.49	238.63	9079	50	2.42	11500.00	237.96
9006	250	0.92	11500.00	239.20	9043	75	-1.06	11429.83	238.54	9080	50	1.73	11500.00	238.45
9007	250	0.43	11500.00	239.31	9044	38	0.51	11500.00	239.18	9081	38	0.69	11500.00	239.11
9008	250	-1.39	11467.50	239.32	9045	50	-2.36	11448.22	238.92	9082	167	-2.84	11477.04	239.52
9009	167	-1.06	11476.48	239.51	9046	38	-1.18	11462.71	239.22	9083	167	-1.25	11483.83	239.66
9010	250	-2.38	11470.06	239.38	9047	50	-2.36	11448.22	238.92	9084	167	-1.64	11478.75	239.56
9011	250	-0.80	11465.97	239.29	9048	50	-1.18	11470.86	239.39	9085	167	-1.54	11478.38	239.55
9012	250	-0.65	11465.61	239.28	9049	38	-1.18	11462.71	239.22	9086	167	-1.20	11483.65	239.66
9013	250	-0.41	11464.99	239.27	9050	38	-1.18	11462.71	239.22	9087	167	-2.46	11481.99	239.62
9014	250	-0.62	11465.53	239.28	9051	38	-1.18	11462.71	239.22	9088	167	-1.54	11478.38	239.55
9015	250	0.56	11500.00	239.39	9052	38	-1.18	11462.71	239.22	9089	75	-1.86	11446.72	238.89
9016	167	-1.72	11479.06	239.56	9053	50	-3.19	11443.73	238.83	9090	50	-2.36	11448.22	238.92
9017	45	5.40	11500.00	238.20	9054	38	-0.35	11449.44	238.94	9091	50	-2.36	11448.22	238.92
9018	167	-1.59	11478.57	239.55	9055	38	-0.35	11449.44	238.94	9092	38	0.99	11500.00	238.82
9019	167	-1.59	11478.57	239.55	9056	38	-1.97	11475.28	239.48	9093	50	-1.18	11470.86	239.39
9020	167	-1.20	11483.65	239.66	9057	50	-0.71	11429.83	238.54	9094	38	-1.18	11462.71	239.22
9021	167	-1.72	11479.06	239.56	9058	38	-0.35	11449.44	238.94	9095	50	-2.36	11448.22	238.92
9022	167	-1.72	11479.06	239.56	9059	50	-0.71	11429.83	238.54	9096	300	36.00	11500.00	238.20
9023	167	-1.76	11479.25	239.57	9060	75	-5.67	11480.33	239.59	9097	38	4.50	11500.00	238.20
9024	167	-1.64	11478.75	239.56	9061	75	-8.15	11488.61	239.76	9098	15	1.80	11500.00	238.20
9025	167	-1.28	11483.97	239.67	9062	50	-2.66	11451.57	238.99	9099	15	1.80	11500.00	238.20
9026	167	-1.59	11478.57	239.55	9063	38	-5.31	11509.62	240.20	9100	50	6.00	11500.00	238.20
9027	167	-1.03	11476.34	239.51	9064	38	-0.50	11425.92	238.45	9101	300	36.00	11500.00	238.20
9028	167	-0.90	11475.84	239.50	9065	75	1.04	11500.00	239.32	9102	75	9.00	11500.00	238.20
9029	167	-1.89	11479.74	239.58	9066	75	9.00	11500.00	238.20	9103	25	3.00	11500.00	238.20
9030	167	-1.76	11479.25	239.57	9067	38	1.83	11500.00	238.21	9104	75	9.00	11500.00	238.20
9031	167	-0.90	11475.84	239.50	9068	38	4.77	11500.00	237.62	9105	1000	-500.00	18837.24	393.13
9032	167	-1.76	11479.25	239.57	9069	38	1.83	11500.00	238.21	9106	4225	507.00	11500.00	238.20
9033	167	-1.59	11478.57	239.55	9070	38	1.83	11500.00	238.21	9107	750	90.00	11500.00	238.20
9034	167	-0.64	11481.37	239.61	9071	38	5.21	11500.00	237.46	9108	2500	300.00	11500.00	238.20
9035	50	-0.71	11429.83	238.54	9072	75	0.72	11500.00	238.96	9109				
9036	50	-2.83	11474.56	239.47	9073	50	0.69	11500.00	239.32	9110				
9037	38	-4.07	11482.25	239.63	9074	38	5.21	11500.00	237.46	9111				

Resident XFMR Table

12KV ONE-LINE DISTRIBUTION

12/18/12
821S

| 824 (SW) | 822 (WEST) |
| 825 (SE) | 823 (EAST) |

823 EAST

822 WEST

824 SW

825 SE
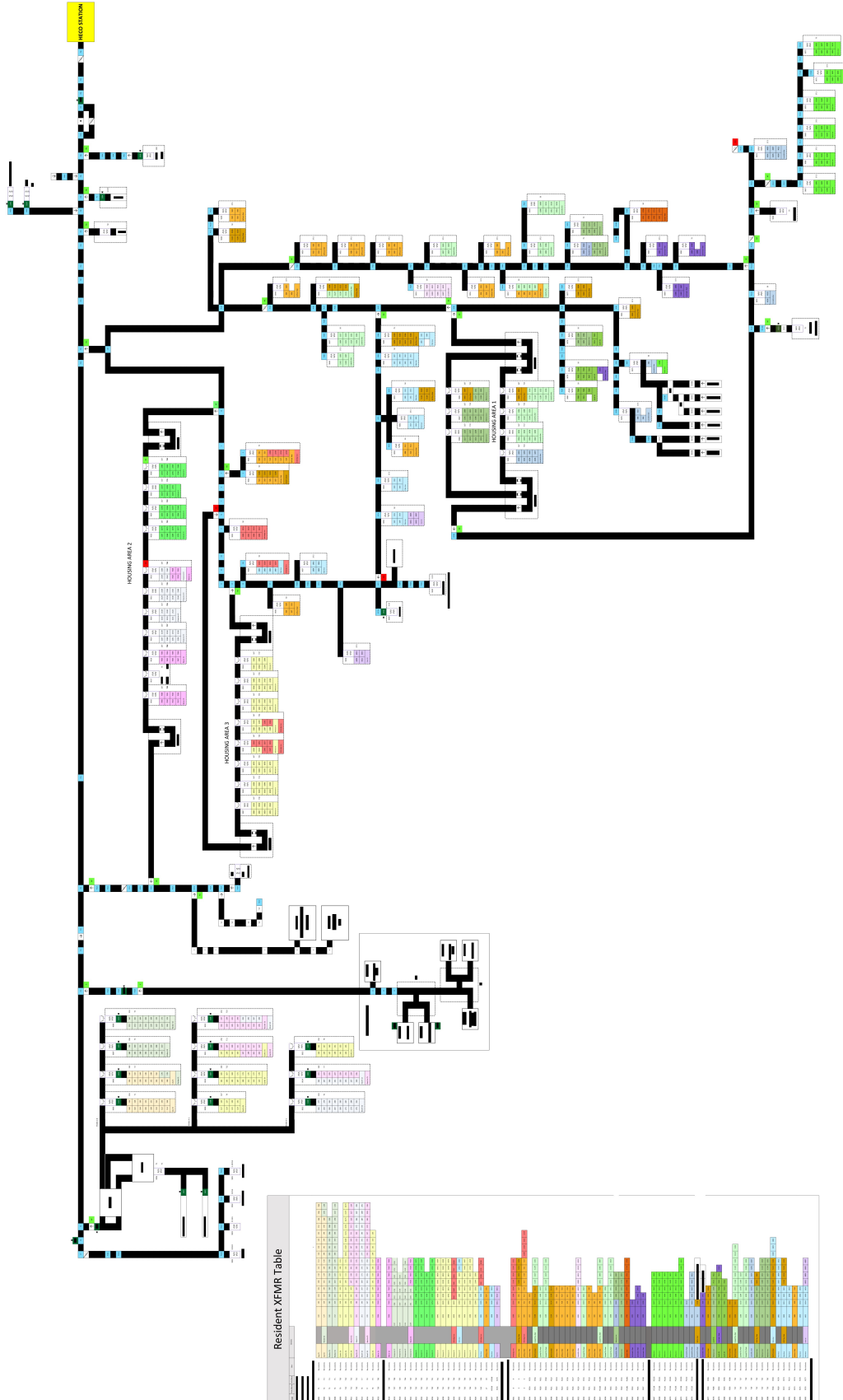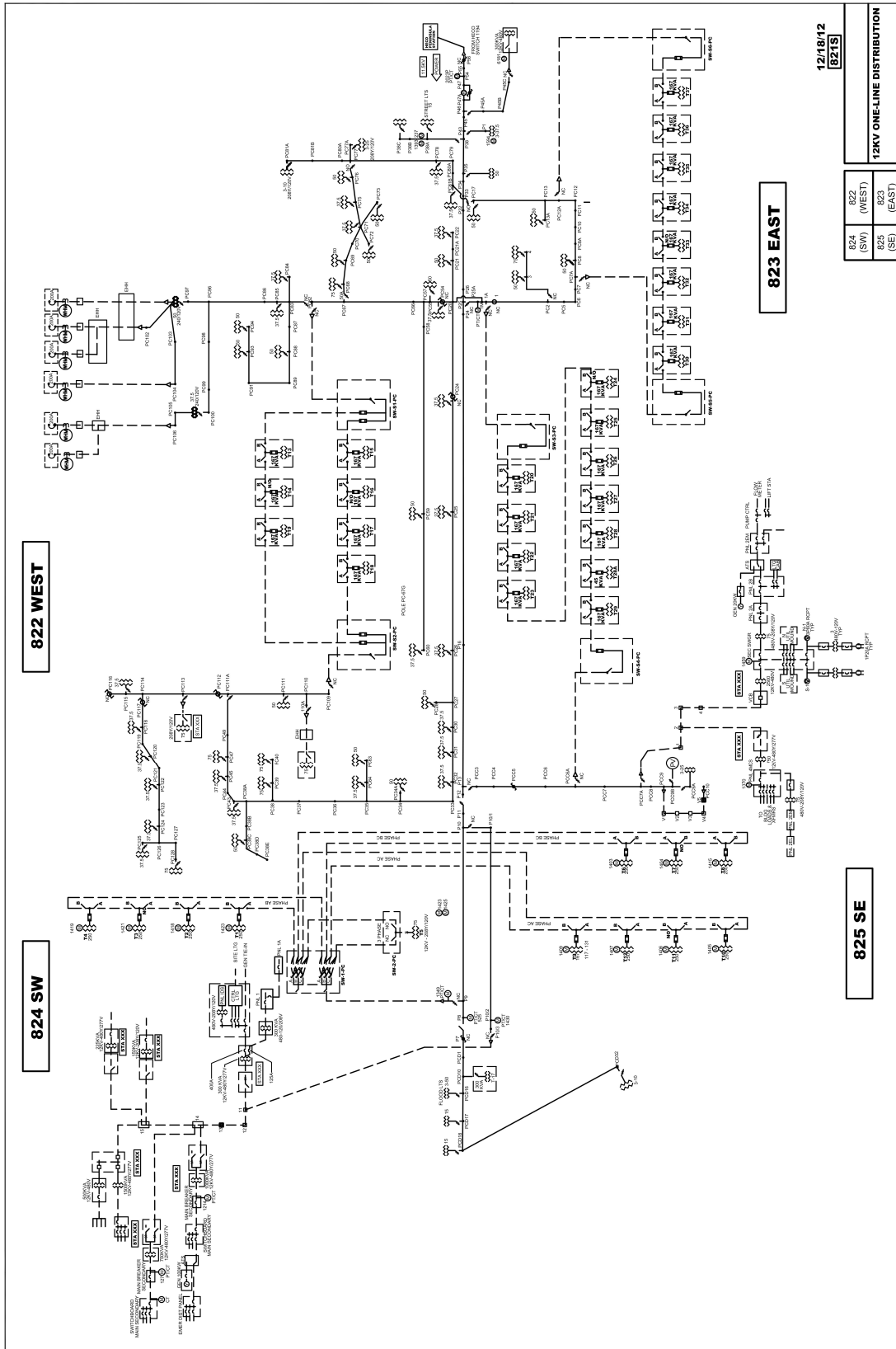
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