VILLAGE OF PAW PAW

ELECTRIC DISTRIBUTION SYSTEM STUDY & FIVE YEAR PLAN

FINAL REPORT
April 7, 2017

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VILLAGE OF PAW PAW
ELECTRIC DISTRIBUTION STUDY & FIVE-YEAR PLAN
EXECUTIVE SUMMARY

The scope of this electric distribution system study was to review the Village of Paw Paw distribution system for equipment and conductor capacity issues, to review service reliability to top critical and load customers, plus to review voltage issues for both current system loads and projected 5 and 10-year load growth. Maximum overcurrent protection equipment and distribution conductor ratings were established for three system conditions: system normal; first contingency outages; and second contingency outages, all at peak load conditions. Additionally, reliability to the Village of Paw Paw's top critical and load customers was assessed. System improvement projects for the next six-years were developed along with associated cost estimates.

The maximum continuous and emergency conductor ampacity ratings and equipment loading limits were established. Conductors will be limited to operate at 50% of their thermal rating for normal system conditions under peak loading conditions and 90% for first contingency operations. Distribution circuit reclosers will be allowed to operate at 40% of nameplate rating for normal operation and 80% for first contingency operations. The equipment and conductor ratings established in this study are goals for the Village of Paw Paw to achieve and are the basis for the analysis and recommendations.

A review of the Village of Paw Paw's distribution circuit reclosers show that the North Circuit recloser is close to the 40% threshold and will be above the loading criteria by 2021. Upgrading this circuit's recloser to a higher ampacity G&W Viper will increase the capacity from 560A to 800A correcting this issue and bringing the equipment in line with the equipment loading philosophy. The South Circuit recloser will be on the threshold of the 40% limit after 2021 and should be upgraded as a future project.

Under 2016 loading, three sections of primary line were found to be loaded above the 50% criteria and one section above 80%. An additional three sections of line will become overloaded due to load growth by 2026 and one section will be above the maximum rating. These sections of line have recommended conductor upgrades in the proposed projects list. Upgrading the conductor to #336.4 ACSR will correct the loading and bring the equipment in line with the equipment loading philosophy. Under 2016 loading eleven of the fourteen circuit ties have backup conductors that are loaded greater than 100%. Under 2021 loading, all of the circuit ties will have backup conductors loaded greater than 100%. All of the circuit ties under 2026 projected loading will have backup conductors loaded greater than 100% and North & South Circuit reclosers will be loaded to 100%. The lack of strong circuit ties is the greatest issue with the distribution system. Without strong circuit ties, customer reliability will suffer. The addition of a new substation and transmission line will improve the reliability to customers by moving the Village of Paw Paw's system from the I&M Interconnection.

Completion of the proposed projects will correct the lack of circuit ties, the overloading of equipment, voltage issues under a 1st contingency outage, and improve the safety & reliability of the distribution system. Several tables, charts, graphs and drawings are included with this report to clearly state system deficiencies and recommended changes proposed herein.

VILLAGE OF PAW PAW
ELECTRIC DISTRIBUTION SYSTEM STUDY & FIVE-YEAR PLAN
BACKGROUND & FINDINGS

The scope of this electric distribution system study was to review the Village of Paw Paw distribution system for equipment and conductor capacity issues, to review service reliability to top critical and load customers, plus to review voltage issues for both current system loads and projected 5 and 10-year load growth. The analysis was performed for normal system conditions plus first contingency distribution circuit outages. Implementation of the recommendations included in this report will maintain conductor and equipment within specified ratings, will balance circuit loads, will increase capacity of distribution circuits and will improve customer reliability.

Study process included:

- Retrieval of system winter and summer peak circuit loads.
- Create working system model from ESRI base provided by Wightman & Associates, Inc. (WAI) including adding source data, conductor characteristics, construction codes, and transformer impedances.
- Integration of customer billing peak load data into model.
- Establish Village of Paw Paw electric system operating philosophy including maximum conductor and equipment loading limits and voltage limits. Conductor thermal loading limits will be the basis for continuous and emergency conductor ampacity ratings.
- Analyze and review system for capacity issues and voltage issues. Analysis will include conductor and equipment loading levels, voltage drop, capacitor placement, and load balancing.
- Perform load growth scenario for 5 & 10 years based on allocation of historical load data. Complete voltage drop and capacity analysis for each load growth case for several system scenarios including loss of a major circuit and loss of a substation transformer
- System analysis will include circuit review utilizing all major circuit ties.
- Analyze system reliability for both large load customers and critical customers.
- Preparation of drawings depicting conductor loading conditions under each load case and recommended conductor changes.
- Prepare construction cost estimates for recommended projects.

System Background Information

Village of Paw Paw's distribution system is comprised of the following:

- Three metered 12.47kV interconnects to Indiana Michigan Power's (I&M) system
- Four 12.47kV distribution circuits
- 20.5 miles of overhead distribution line
- 7.1 miles of underground distribution line
- 1,992 electric service meters
- Non-coincidental system peak of 10.7MW

Each of these distribution circuits are supplied electric service by one of three metering interconnection points to the I&M system.

- Berrien Street (Substation) – Located across from the Department of Public Services
- Family Fare – Located in the back of parking lot of Family Fare
- Johnson Road (RR Tracks) – Located along the RR Tracks near Ampey Street

Village of Paw Paw's distribution circuits each have a name identifying the geographic area that they provide electric service to. The four distribution circuits and their metering interconnection points are.

- Almena Circuit – Berrien Street (Substation) I&M Interconnection
- North Circuit – Johnson Road (RR Tracks) I&M Interconnection
- South Circuit – Johnson Road (RR Tracks) I&M Interconnection
- Walmart Circuit – Family Fare I&M Interconnection

With each circuit being interconnected and served by I&M, reliability to the distribution system depends on the I&M interconnections being available. If the interconnection to I&M's system is lost, the Village of Paw Paw circuits may not be able to provide service to its customers. Coordination of protective devices and reliability will be increased with the addition of a transmission line and substation. Transmission lines and substations are inherently more reliable than a distribution line. This is due to, but not limited to, construction grades, equipment overload factors, vegetation issues, and a smaller geographical footprint.

Electric System Model

A computer model of the Village of Paw Paw's electrical system was created for use in Milsoft's Windmil Engineering Analysis software and includes overhead conductors, underground cables, transformers, switches, protective devices, capacitors, and electric meters. The model was created using the ESRI mapping based on field observations, meetings with Village of Paw Paw staff, and review of historical mapping.

Circuit loads for the system in 2015 were measured and recorded by the line workers and were applied to the 12.47kV reclosers in the model. Load was distributed throughout the model using Windmil's load allocation tool based on meter reads and recorded amps at the circuit reclosers.

System Load Allocation

I&M provided historical loading on the three metering interconnection points. Since this is a system capacity and planning study, worst case (peak) load data was utilized. System load data from September 1 & 2, 2015 was utilized in this study since this was the most recent high load days. The electrical system is currently loaded to 22.5% of total distribution circuit recloser capacity. A graph of anticipated load is provided in the attachments section of this report. Note that I&M provides load data in megawatts (MW) which is "real power." System capacity and loading must be analyzed on an MVA basis which includes reactive power (VAR's). All historical MW loads supplied by I&M were converted to MVA based on the provided historical power factors at each metering interconnection point. Graphs and charts contained in this report reflect MVA loading.

Proper load allocation on the system within the computer model is key to accurate analysis results. Importing of individual customer billing data provides the most accurate results. A billing file was provided by Wightman & Associates that contained 1928 customers kWh usage and 35 customers kW demand. Load was first allocated based on the customer's kW demand (where known) and second based on customer's kWh usage over one billing cycle. Load Control Points (LCP's) were created for each distribution circuit using the distribution circuit reclosers. LCP's control the amount of load to be distributed downline and the consumers meter reads drive how it is applied throughout the circuit.

To allow the system model to converge, secondaries, service wires, and distribution transformers were not modeled or were removed from the electric model. This made the model a pure primary system (12.47kV) model. In order to account for loss beyond the primary system, an assumed loss of 4% was applied to account for the losses due to the removed transformers and secondary conductors. This is a typical method of load allocation when completing a study loading on primary lines.

<u>Load Growth & Additions</u>

Village of Paw Paw did not provide any historical loading data for this study. To the best of our knowledge, the Village of Paw Paw also has never had a study completed to determine anticipated load growth. At this time, there are no anticipated large load additions to the Village of Paw Paw's electric system.

Growth in peak demand for Village of Paw Paw's electric system is projected to be 1.5% annually for residential customers and 3% for commercial/industrial customers for the next ten years. This is an estimate based on similar sized municipal electric systems, located in villages with similar demographics. Spot loads of 0.5MW were placed on Gremps and Ampey Roads and applied to the 2017 & 2019 loading. The table below gives the projected MW demand, MVA demand, and MWh.

Load Projections

Year	MW Demand	MVA Demand	MWh
2016	9.8	10.9	52,320
2017	11.1	12.3	59,080
2018	11.2	12.5	59,967
2019	12.6	14.0	67,079
2020	12.8	14.2	68,085
2021	13.0	14.4	69,107
2022	13.2	14.6	70,143
2023	13.3	14.8	71,195
2024	13.5	15.1	72,263
2025	13.8	15.3	73,347

*Annual escalation factor of 1.5% for energy & demand.
Power factor estimated at 90% lagging.

Key Customer Reliability

Due to a lack of outage indices, the following criteria will be used to determine if Village of Paw Paw's top critical and large usage customers have reliable and robust electric service.

- Available backup circuit ties.
- Alternate I&M metering interconnection point

A list of the large load and critical customers was developed for this study. These included utility buildings, medical facilities, governmental and public safety buildings, large commercial and industrial, plus water and waste water installations. Tables are included after this section of the report.

Conductor & Equipment Ratings

In order to evaluate distribution circuit capacity, not only must system load be determined, but maximum equipment and conductor ratings must be established. Ratings utilized in this study were established for three system conditions:

1. Normal – All substation transformers and distribution circuits in service, bus tie and circuit tie switches open.
2. First Contingency – One substation transformer, distribution circuit recloser out of service, bus tie switch/circuit tie switch closed. No loss of customers.
3. Second Contingency – Two substation transformers, distribution circuit reclosers out of service, bus tie switch/circuit tie switch closed. Loss of customers.

Protective devices (circuit reclosers) and distribution circuit conductor, regardless if overhead or underground, will be allowed to operate at 50% of maximum nameplate or thermal rating for normal system conditions, 90% for 1st contingency outages, and 100% for 2nd contingency outages.

Maximum ratings for protective devices are provided by the manufacturers and are listed on equipment nameplates. Due to the lead time associated with reclosers, maximum continuous loading should not exceed nameplate ratings.

Overhead conductor ratings are more difficult to establish than equipment ratings since the calculations include thirteen variables including selecting maximum temperature often based on unknown design conditions. The ampacity (thermal) ratings of overhead conductors on Village of Paw Paw's system were determined by the following variables:

- 104°F (40°C) Ambient Temperature
- 167°F (75°C) Conductor Temperature *(Normal & 1st Contingency)*
- 212°F (100°C) Conductor Temperature *(Emergency)*
- 2ft/sec wind speed (utility standard)
- Additional eleven variables using a conservative approach.

Standard ACSR conductors can be operated continuously up to 212°F, but system design (sag & clearances) must reflect this rating. Conductor sag at 212°F was likely not factored into majority of overhead circuit design, therefore a more conservative rating (167°F) is prudent to use for normal system conditions. The higher (212°F) thermal rating can be used for emergency operations, but close physical review of sag under these conditions should be undertaken, especially if conditions extend for several hours or longer. Higher short term emergency ratings for overhead and underground conductors can be utilized under extreme conditions. Shortening the lifespan of conductor by operating it above its maximum thermal rating is not the problem that operating transformers above their ratings is. Conductor is relatively low in cost and easily replaceable compared to substation transformers.

Underground conductor ratings were determined based on cable characteristics and installation method based on conductor size.

- 90°C Conductor Temperature *(Normal & 1st Contingency)*
- 105°C Conductor Temperature *(Emergency Rating)*
- 20°C Earth Ambient Temperature
- 75% Load Factor
- Conductors up to #4/0 AL 15kV 1/3rd Concentric Neutral – direct buried, one circuit.
- Large conductors, including all tape-shield power cable – two-way duct bank.
- 133%, EPR conductor insulation.

A table listing the loading conditions outlined above is attached to the end of this report. Distribution conductor ratings were updated in the Village of Paw Paw's computerized distribution system (WindMil) model utilized for this system analysis.

<u>Voltage Limits</u>

Primary system voltage limits were established based on published ANSI and MPSC voltage ranges. These ranges for voltage at the point of service were the basis for this study. The range of service utilization voltage under normal system conditions is ±5% of 120V (114V – 126V). Since the secondary, service wire, and transformers were removed from the model for load allocation convergence, voltage drop was calculated on the primary system only. Case studies of both rural and municipal systems show that more than 99% of customers have less than a 4.0V drop due to secondaries, services, and transformers. Therefore a lower limit of 118V was used to account for voltage drop across the transformer and secondaries up to the customer's service entrance. This allows for 4V drop on secondaries and services not included in the current system model.

Equipment Maintenance

Considering that the Village of Paw Paw does not own or operate an electric substation, there are few items that require routine maintenance. Distribution items that should be regularly maintained include:

- Oil-filled reclosers
- Single-phase disconnect switches
- Three-phase gang-operated switches
- Capacitor Banks

Recloser maintenance cycles vary depending on the number of operations and fault current interrupted, insulating medium (e.g. oil, air, SF6 gas, etc.), and atmospheric conditions. All reclosers on Paw Paw's system are Cooper, oil-filled, WE reclosers. Cooper provides very detailed maintenance instructions in their service bulletin for these reclosers. Based on the recommendations outlined by Cooper, the reclosers should be maintained at least every three years. Inspections should include checking the recloser for physical damage and oil leaks, checking the insulators for cracks, breaks or burn marks, cleaning of the insulators, checking all mechanical connections for proper torque, and performed a dielectric withstand test. The reclosers should be untanked and all internal parts cleaned and inspected. The insulating oil should be tested for proper dielectric strength, cleaned of carbon deposits and sludge. Finally, a check for hot spots should be completed using a thermal imaging camera.

The frequency of visual inspection and operational testing of single-phase disconnect and three-phase gang-operated switches depends on the number of operations, exposure to high fault currents, atmospheric conditions, and utility standards. These switches may not require attention for many years, but visual inspections and checks for hot spots with a thermal imaging camera should be completed annually. Additionally, testing and operation of critical three-phase tie switches should occur annually. When switch maintenance is performed, it should include inspecting insulators for cracks, breaks or burn marks, cleaning of the insulators, inspecting contacts for alignment and burn marks, inspecting operating rods, bearings, and linkages for correct alignment and operation, and checking all mechanical connections for proper torque. Also, follow the maintenance instructions provided by the individual switch manufacturer.

Capacitor banks should be inspected and tested for proper operation annually. Inspections should include checking the capacitors for physical damage, bulges, leaks or discoloration, checking the insulators for cracks, breaks or burn marks, cleaning of the insulators, checking all mechanical connections for proper torque. A check for hot spots should be completed using a thermal imaging camera. Capacitor banks with vacuum or oil switches should be opened and closed to verify correct operation.

Circuit Recloser Loading

Considering under 1st contingency outage conditions that no loss of service to customers will be allowed, circuit recloser capacity must be sufficient enough to support the loss of any other circuit recloser on the system under peak load conditions. Currently all of the circuit reclosers on Village of Paw Paw's system are operating at or below the 40% threshold for a normal system, peak load condition. Refer to the Circuit Recloser Loading – System Normal Peak Conditions 2016 chart.

Under a 1st contingency outage condition circuit reclosers will be allowed to operate at 80% of maximum rating. This provides capacity for short-term spikes in load, unplanned load growth, and additional load transfer in the event of a 2nd contingency condition. Refer to the Protective Equipment & Conductor Loading Limit Diagram attached to this report.

2016

Under 2016 loading, none of the distribution circuit reclosers on the Village of Paw Paw system are loaded at or above the 40%.

Recloser Loading

Recloser	Rating (MVA)	Loading (MVA)	% Max
Almena	12	1.8	15.3%
North	12	4.7	39.2%
South	12	3.3	27.5%
Walmart	12	1.1	9.2%

In the event that any distribution circuit recloser is lost, there is sufficient capacity for another circuit recloser to carry the load. Under a first contingency loss of any circuit recloser, none of the backup circuit reclosers would be loaded above the established 80% threshold. Although, the backup circuit conductors would be loaded above 80%, refer to the Circuit Recloser Loading – System Normal and Recloser Out of Service 2016 charts.

2021-2026

Including anticipated loading over the next ten years, total distribution circuit loading is projected to be at 32.1% of existing available capacity. The North circuit recloser will be loaded above the established 40% limit under normal conditions and the South circuit recloser will be at the 40% limit. Under a first contingency loss of one distribution circuit recloser, the North & South circuit reclosers would be loaded above the 80% threshold. Refer to the Circuit Recloser Loading – System Normal and Recloser Out of Service 2021/2021 charts.

Key Customer Reliability

Tables have been prepared listing the critical and large usage customers. These tables were utilized in the evaluation for reliable service to these customers. As stated earlier, these included utility buildings, medical facilities, governmental and public safety buildings, large commercial and industrial, plus water and waste water installations. Refer to the Critical and Large Load Customers table included within the report.

Village of Paw Paw has backup ties to 54% of its critical and large load customers with a total 38% of those customers having ties feeding from an alternate metering interconnection point. The ties were reviewed under the peak loading of the year 2016.

The reliability to key customers is being affected by the lack of full capacity ties and ties to alternate I&M sources. Rebuilding the circuits and increasing the conductor size will create ties that can be used on the peak day. Circuit conductor rebuilds should be located such that the full capacity ties are to alternate I&M sources.

Due to a lack of historical outage data, performance indices could not be evaluated.

Distribution Circuit Loading

Consistent with the distribution circuit recloser outage conditions, no loss of service to customers will be allowed under 1st contingency distribution main circuit outage conditions. This will apply to mainline sections of distribution circuits. Village of Paw Paw's distribution circuits all have normally open tie points to at least one other circuit. Limiting distribution circuit loading to 50% of conductor ampacity allows for one distribution circuit to be out of service and a backup circuit to carry all of the load under peak system conditions. Under this 1st contingency outage condition the conductor will be allowed to operate at 90% of its thermal rating. Short-term spikes in load will be covered by utilizing the emergency conductor ratings. Refer to the Protective Equipment & Conductor Loading Limit Diagram.

2016

Based on 2016 peak load conditions, 25% of Village of Paw Paw's four distribution circuits are operating above their 50% rating. Refer to Village of Paw Paw Circuit Loading 2016 chart. Mainline, three-phase circuit conductor loading was analyzed for 2016 peak load, plus five and ten year load growth at 1.5% per year. Conductor loadings are highlighted on the attached drawings based on four levels <50%, 50 – 80%, 80 – 100%, and >100% of the rated ampacity. Following the conductor rating discussion above, under normal system peak conditions, conductors operating at or above 50% of their rated ampacity should be increased in size or have load shifted to other circuits.

Primary conductor sections operating above 50% of their thermal rating at peak 2016 loading:

- North Circuit - #2 AL Mainline section of this circuit feeding underground riser at the corner of W. Michigan Avenue and Hazen Street.
- North Circuit - #336.4 ACSR – Mainline section of this circuit from distribution line recloser, along south Gremps Street to west Michigan Avenue.
- South Circuit - #1/0 ACSR along M-40 from Industrial Ave. to Fadel St.

Primary conductor sections operating above 80% of their thermal rating at peak 2016 loading:

- South Circuit - #1/0 ACSR along Commercial Avenue from Lake Boulevard to M-40.

<u>2021</u>
A review of the distribution circuits following five-year load growth and anticipated load additions shows the following sections of line operating above 50% of their thermal rating:

- North Circuit - #2/0 ACSR along Hazen Street from W. Michigan Avenue to W. North Street.
- North Circuit - #2 ACSR along W. North Street from Hazen Street to N. Miller Street.

<u>2026</u>
A review of the distribution circuits following ten-year load growth and anticipated load additions shows capacity issues (>50%) in addition of the 2016 and 2021 issues developing on the following line sections:

- South Circuit - #336.4 ACSR along from circuit recloser to Commercial Avenue is loaded above 50%.

- South Circuit - #1/0 ACSR along Commercial Avenue from Lake Boulevard to Cherry Street is loaded above 100%.

- South Circuit - #1/0 ACSR along M40 from Commercial Avenue to Fadel Street is loaded above 80%.

These loading conditions will need to be further reviewed in future studies as system changes are implemented and load increases are accurately measured.

<u>System Loading – Mainline Circuit Ties</u>
Conductor and equipment loading levels were evaluated for all fourteen full-capacity circuit ties at peak load conditions. The Circuit Backup Review tables attached to this report list the ties for the four main distribution circuits on Village of Paw Paw's system. Highlighted values represent distribution circuit reclosers operating above 80% and conductors operating above 90% when carrying the load of an adjacent circuit.

<u>2016</u>
Under 2016 peak loading conditions eleven of the fourteen distribution circuit ties available in 2016 are above the established 90% criteria and all eleven of them are at or above 100%. (Refer to Circuit Backups - 2016 Loading.) 50% of the four distribution circuits do not have a backup tie due to the backup circuit conductor being overloaded. The North Circuit is the only circuit that has more than one backup tie. The South Circuit has only one backup tie circuit and Almena has none that are not overloaded for the peak day loading in 2016. Furthermore, the Walmart Circuit

does not have any backup circuit ties. In the event that the Walmart Circuit recloser was to fail, this circuit would be out of service until repairs to the recloser could be completed. Backing up any circuit by closing a tie switch will not cause the backup circuit recloser to operate above the contingency rating. Of the eleven circuit ties that would exceed their first contingency rating, only the backup conductor is over-dutied and equipment is within set ratings.

<u>2021</u>
Under 2021 peak loading conditions all of the fourteen currently available distribution circuit ties are operating above above 100%. (Refer to Circuit Backups - 2021 Loading.) Backing up the North Circuit to the South Circuit or vice versa will cause the distribution circuit recloser to operate above the contingency rating. The Almena and Walmart Circuit have no available backup ties under peak loading conditions for 2021.

<u>2026</u>
Under 2026 peak loading conditions all of the currently available fourteen distribution circuit ties are operating above above 100%. (Refer to Circuit Backups - 2026 Loading.) All of the circuits do not have an available backup and load would need to be shifted from the backup circuit or shed in the event of a circuit outage. Backing up the North or South circuit by closing a tie switch will cause the distribution circuit recloser to operate above the maximum rating.

Additional circuit ties and backfeeding capabilities exist with the use of "Normally Closed" switches on the system. As unique switching arrangements are required, analysis should be completed on a case-by-case basis. Additionally, circuit ties completed at non-peak times should be individually reviewed.

Voltage Drop Analysis

Voltages were calculated on the system under peak loading conditions with the system in the following conditions:

- All circuit switches in normal state.
- Fixed and switched capacitor banks on and off.
- All generation off.
- Line to Line voltage at the distribution circuit reclosers assumed to be 12,782V (123V).

Analysis completed in the WindMil system model shows that no sections of the four distribution circuits have a calculated voltage on primary line sections <118V at peak 2016 loading conditions with capacitor banks on or off. As noted previously, the voltage limit on the primary system is limited to 118V to allow for a 4V drop through distribution transformers and secondary services.

<u>2016</u>
Low voltage issues at 2016 peak load conditions with capacitors off:
- No deficiencies were found.

Low voltage issues at 2016 peak load conditions with capacitors on:
- No deficiencies were found.

2021

Low voltage issues at 2021 peak load conditions with capacitors off:

- No deficiencies were found.

Low voltage issues at 2021 peak load conditions with capacitors on:

- No deficiencies were found.

Analysis completed in the WindMil system model shows that no new sections of the circuits in addition to 2016 loading have a calculated voltage on primary line sections less than 118V at peak 2021 loading conditions with capacitor banks off or on.

2026

Low voltage issues at 2026 peak load conditions with capacitors off:

- A majority of the North Circuit in the areas north of W. Michigan Avenue.

Low voltage issues at 2026 peak load conditions with capacitors on:

- North Circuit along Glenview Drive.

Analysis completed in the WindMil system model shows that no new sections of the circuits in addition to 2021 loading have a calculated voltage on primary line sections less than 118V at peak 2026 loading conditions with capacitor banks off or on.

Voltage conditions for circuit ties under a 1st contingency state were reviewed. Only circuits that were not already flagged as having a backup circuit or other equipment being over capacity were reviewed.

Low voltage issues for circuits tied together under a 1st contingency at 2016 peak load conditions with capacitors off:

Low Voltage – 2016 Circuit Ties/Backups
Capacitors Off

Circuit Out-of-Service	Backup Circuit	Location / Area
North	Almena	All areas on Hazen Street to the north of W. North Street. Service area along W. North Street, through the underground and up to the Open switch near W. Michigan Avenue.
North	South	All of the North Circuit. South Circuit along M-40, continuing down Ampey Street and to the tie switch on Johnson Street.
South	North	M-40 north of Fade Street. All sections on circuit downline from M-40 and Commercial Avenue.

Low voltage issues for circuits tied together under a 1st contingency at 2016 peak load conditions with capacitors on:

Low Voltage – 2016 Circuit Ties/Backups
Capacitors On

Circuit Out-of-Service	Backup Circuit	Location / Area
North	South	All of the North Circuit. South Circuit areas along Ampey Street and along Johnson Street to the tie switch.

Village of Paw Paw has three circuit ties that were evaluated for voltage drop. All of the configurations will result in low voltage conditions on the peak loading day when capacitor banks are not in service. One of the configurations will result in low voltage conditions on the peak loading day when capacitor banks are in service. When the North Circuit is tied to the Almena Circuit using the cut-outs near Michigan Avenue, they will be over the 200A rated capacity of the units. A total of 7% of the circuit ties can be used on the peak loading day without overloading any conductors, protective equipment devices, or creating low voltage conditions.

2021-2026
A review of the distribution circuit ties for a 1st contingency following five-year load growth was completed for ties that did not have either a backup conductor or any other equipment that was not overloaded. Circuit ties that were flagged under 2016 loading to have low voltage conditions were also not reviewed. Following voltage drop analysis for circuit ties under 2021 & 2026 peak loading, no new low voltage issue were found.

Reconductoring of circuits with larger conductor will decrease the voltage drop and improve voltage under both normal operating conditions and when utilized as circuit ties. Voltage measurements should be taken during peak load conditions to verify the results of the computer model analysis prior to implementing projects based solely on voltage conditions.

Load Balancing

A balanced distribution system has lower losses than the unbalanced case. Although completely balanced circuits are ideal, it is not always possible to achieve. All distribution circuits were analyzed for unbalanced loading conditions and corrective action through several methods:

1. WindMil's Load Balance routine.
2. Review of total connected transformer kVA.
3. Evaluation of phase loading from historical distribution circuit recloser loading data.

Calculating the phase imbalance was completed by subtracting the maximum from the minimum current magnitude and dividing that value with the least loaded phase. Village of Paw Paw should set a goal of maintaining no greater of an imbalance than 40% and take corrective action above

49%. The table below gives the 2016 phase loading & percent imbalance where circuit data was available.

Circuit loading per phase under peak conditions showed one circuit to have significant load imbalance and one that should be reviewed anually. This imbalance, causes difficulty in the analysis and operation of the system as all conductors and equipment must be sized to handle load on the highest phase. System loading spreadsheets attached to this report are based on loading of the highest phase. All circuit loading data was provided by I&M reports and by the Village of Paw Paw from manual recloser readings.

Circuit Loading

Circuit	AØ	BØ	CØ	Imbalance
Almena	70	100	115	64.3%
North	217	187	154	40.9%
South	137	151	148	10.2%
Walmart	44	44	50	13.6%

Methods for correcting loading imbalance are provided in the recommendations. The amount of current in amps and the phase the load is to be shifted from are in the Phase Balancing section of the recommendations. Some phase imbalance may also be on the customer side of the system and may not be able to be balanced.

Asset Condition

An evaluation of the condition of the Village of Paw Paw's distribution system was completed as part of this study. The primary equipment was assessed and ranked a condition of Good, Fair, or Poor. Good condition equipment was visibly free of any defects, paint was not showing age, coatings were intact, and connectors were crimp style. Fair condition equipment was starting to visibly show signs of wear, had minor rust or wearing of paint, or conductors were spliced together. Poor condition equipment was visibly damaged, had extreme rust, was losing insulation, or had multiple splices in the conductor. The findings of the assessment are highlighted in the table below.

Asset Condition

Asset	Unit	Total	Good	Fair	Poor
Reclosers	Each	4	0%	100%	0%
Capacitor Banks	Each	6	100%	0%	0%
Primary Conductor	LFT	108,467	62%	35%	3%
Pole Mount Transformers	Each	291	45%	44%	11%
Pad Mount Transformers	Each	103	58%	35%	7%

*Condition of assets listed based on a visual inspection. Refer to the pole inspection report for condition of poles.

Criticality of Assets

The criticality of assets on the electric distribution system were evaluated based on ten factors. Considering the distribution system is comprised of many individual pieces, segments were grouped together. These included sections of three-phase mainline, major three-phase leads off the mainline circuit, and single-phase taps. Not all individual pieces of equipment were evaluated due to the number that would need to be listed. Examples are poles and transformers. Only the largest transformers or those serving large or critical customers were included. Evaluation factors for the loss of an item/segment included:

- Number of customers impacted
- Impact on large and/or critical customers
- Impact on the community
- Single-point of failure on the system
- Maintenance history / reliability
- Probability of failure
- Safety Impact
- Lead time to obtain spare/replacement
- Cost for replacement
- Utilization rate

Assets were scored on these factors with an individual score ranging from 0 to 10. Assets with a rating of 60 or greater are highlighted in the attached table showing the parts of the electrical system that are the most critical. Reclosers and mainline sections of circuit that have no backup at peak times where given high numbers. The most critical pieces of Paw Paw's electric distribution system are the reclosers, three-phase mainline sections, and large transformers serving high load and critical customers. Priority in electrical system capital plan projects and investments should include the most critical items. Refer to the "Critical Assets" table attached to the end of this report.

VILLAGE OF PAW PAW
ELECTRIC DISTRIBUTION SYSTEM STUDY & FIVE-YEAR PLAN
RECOMENDATIONS

The following recommendations are based on the findings and analysis stated above including conductor and equipment loading at normal and first contingency operations (one circuit or distribution recloser), established acceptable service voltages, balanced circuit loads, and need to improve system reliability to critical and large load customers. Implementation of these recommendations will work to bring the electrical distribution system within the required parameters established herein, improve flexibility in system operation, and improve overall system reliability.

Substation Projects

The Village of Paw Paw currently does not have a substation. All of their load is served by interconnection points to the I&M 12.47kV distribution system. Serving load in this fashion is not as reliable as load served by a transmission source and the cost of energy is greater. Furthermore, having a substation with a transfer bus increases the reliability of the circuits by creating a tie point between all circuits that does not affect the voltage as greatly, if at all, as a field tie switch. A substation should be located central to the load. The property on S. Gremps St. being used as a storage yard for the DPW is a prime location. As substations can take several years to plan and construct, it is imperative that the Village of Paw Paw begins planning as soon as possible.

2020

Project #	Circuit	Description
#108	Sub	Replace the existing Cooper Kyle "WE" recloser with a G&W Viper with an SEL-351R controller on the North Circuit. The existing recloser is currently loaded to 39.2% and will be loaded to over 40% by 2021. Replacement will keep the circuit recloser operating within the established capacity limits. Estimated cost $34,500.

2021

Project #	Circuit	Description
#110	Sub	Construction of a new substation with a 12/16/20 MVA power transformer, high and low side relaying, 4 distribution circuit exits, main bus, transfer bus, and control building. Estimated cost $2,730,000.

Transmission Line Projects

The Village of Paw Paw does not currently own any transmission, the construction of a new transmission line will be required in conjunction with the new substation project. AEP has a transmission line routed on the south side of I-94. As it can take several years to plan and complete a transmission project, discussion with AEP should begin immediately.

2021

Project #	Circuit	Description
#111	N/A	Construction of 1.1 miles of new transmission line commencing at an AEP three terminal tap and ending at the new substation site. Transmission line will be designed using traditional round wood pole, plus two self-supporting laminated wood poles at the new proposed substation site. Conductor will be #477 ACSR on linepost insulators with a static ground wire. Entire transmission line will be designed for double circuit three phase underbuild. Estimated cost $820,000.

Distribution Line Projects

Considering the fact that sections of the Village of Paw Paw's distribution circuits are operating above the 50% rating under peak system conditions and nearly all of the available circuit ties would cause the backup circuit conductor to be loaded above capacity, several conductor upgrades projects are required.

There are no ties from the Walmart Circuit to another circuit. This leaves no backup options should the circuit recloser or interconnection to I&M become out of service. There are two critical customers on this circuit and therefor correcting the lack of an additional tie will be a priority and addressed with Project #101.

2018

Project #	Circuit	Description
#101	Walmart	Install approximately 1,250' of #500CU underground cable from a new riser pole on the South Circuit, to be located at the end of Ampey St. Cable would run south and cross under I-94 and continue to the Bronson Lakeview Outpatient Center where it would connect to the existing Walmart Circuit. This will correct the lack of ties to the Walmart Circuit, give the Walmart Circuit another I&M source, and improve reliability to the customers on the Walmart Circuit. Note: the conductor to Bronson Outpatient will be utilized in a backfeed to Walmart and may be undersized for the Walmart load. Estimated cost $173,000.
#102	South	Rebuild South Circuit overhead line along Commercial Ave. from Lake Blvd. to M-40 (0.25 miles) with #336.4 ACSR. This will increase the capacity and correct the loading issues on this section of line. Estimated cost $46,250.
#103	All	Verify and replace fuses as needed per the recommendations of the 2017 Coordination Study. Estimated cost $21,150.

2019

Project #	Circuit	Description
#104	North	Rebuild North Circuit underground from W. Michigan Ave. to Hazen St. with 600' of #500CU. This will increase the capacity of the circuit and correct the loading issues on this section of line. Estimated cost $86,000.

Project #	Circuit	Description
#105	South	Rebuild South Circuit overhead line along M-40 from Berrien St. to Ampey Rd. (0.5 miles) with #336.4 ACSR. This will correct loading issues on the circuit and build a full capacity tie to the Almena Circuit. Estimated cost $93,750.

2020

Project #	Circuit	Description
#106	Almena	Rebuild Almena Circuit overhead line along S. Niles St. from E. Berrien St. to the normally open switch, south of Oak St. (0.2 miles) with #336.4 ACSR. This project will create a full capacity tie to the North Circuit that is served by an alternate I&M source. This project should be done in conjunction with Project #107. Estimated cost $40,500.
#107	North	Rebuild North Circuit overhead line along S. Gremps St., north to Oak St, east to N. Niles St., and south to the normally open switch tie to the Almena Circuit (0.3 miles) with #336.4 ACSR. This project will create a full capacity tie to the Almena Circuit that is off an alternate I&M source. This project should be done in conjunction with Project #106. Estimated cost $58,000.
#109	North	Perform a Thermal Upgrade Study on the North Circuit starting at the circuit recloser and continuing along S. Gremps St. to W. Michigan Ave. This section of line has loading issues based on the #336.4 ACSR being rated at 167°F. Increasing the thermal rating to 212°F will correct the loading issue on this section of line. Estimated cost $58,000.

2022

Project #	Circuit	Description
#112	South	Rebuild South Circuit overhead line along Ampey St. from the underground riser to M-40 (0.6 miles) with #336.4 ACSR. This create a full capacity tie between the North and South Circuits. This tie will correct the low voltage issues that result from tying the two circuits together on the peak day. Estimated cost $122,500.

Phase Balancing

Distribution circuits Almena and North need their loading per phase balanced to improve efficiency, reduce line losses, improve voltage, and reduce total loading per circuit. The North Circuit is above 40%, but below the 49% criteria for taking action. However, there are loading and tie issues on the North Circuit on the peak day that can be mitigated by balancing the phases now. Balancing the phases will improve Village of Paw Paw's ability to tie circuits together, as the highest loaded phase is the limiting factor when making distribution ties. Village of Paw Paw should take specific spot load measurements on peak load days to verify which areas of the system are responsible for the unbalanced conditions.

The following circuits should be re-phased to improve load balance on the distribution circuits. These recommended changes are based on the phasing in the WindMil system model. Actual field conditions may vary and field measurements shall be taken to verify proposed changes are correct.

Phase Balancing

Circuit	Load	Existing Phase	Proposed Phase	% Imbalance After Change
Almena	15A	CØ	AØ	5.3%
North	30A	AØ	CØ	1.6%

Future Projects

System improvements will always be required and not all projects necessary are in the six-year capital list completed herein. Projects that are on the horizon may be impacted by amount of load growth and timing of that growth, coordination with other infrastructure projects, and actual completion dates of the proposed projects. Three system projects are highlighted below.

Extension of the three phase on the Almena Circuit alone 53rd Street to 36th Street and south to the North Circuit at Lake Street. This will create another tie between the two circuits adding redundancy and reliability to the circuit and customers served by these circuits. New overhead conductor shall be #336.4 ACSR.

Conversion of the single phase line to three phase on the Almena Circuit along S. LaGrave Street to I-94 with #336.4 ACSR. The end of the line would riser down with #500 CU, bore the highway, and continue to the switchgear on the Walmart Access Drive. This would complete a loop around the Village of Paw Paw's system. This will increase the number of switching options and improve reliability to the entire system.

Upgrading the mainline underground on the Walmart Circuit to #500 CU and upgrade all the elbows and sectionalizing cabinets to 600A capacity. This give full capacity to all the new ties to the Walmart Circuit. This will increase the capacity of the circuit ties and allow for more switching options on the peak load days.

The Village of Paw Paw should review the extents of their system and the ability to serve future load growth in the surrounding area, especially the area south of I-94.

Conclusions

Completion of a review of the Village of Paw Paw's distribution system for equipment and conductor capacity issues under several system scenarios for both current system loads and projected 5 and 10-year load growth shows deficiencies exist. The most significant issues are conductor loading and backup circuit ties.

The distribution system requires improvements to bring conductors within operating philosophy, to provide reliable backups to critical and large load customers, to eliminate voltage issues, and to rebuild aging overhead circuits. Priority has been given to overloaded line sections, backups to critical customers and top load customers, circuits with voltage issues, then condition.

Reliability to the Village of Paw Paw's distribution system and customers is completely contingent upon the availability of the I&M distribution system and the interconnection points. Any interruption to the I&M distribution system that serves the Village of Paw Paw's circuits, will result in a loss of service to that circuit. For the Walmart Circuit, if there is an outage on the I&M distribution system that serves the circuit, there is not an available backup tie that can be operated by the Village of Paw Paw. The North and South Circuits are interconnected to the same I&M source. Loss of this interconnection would result in approximately 840 customers experiencing an outage. Any outage could potentially last until the I&M source is restored. The I&M sources are at the distribution level and as mentioned, are not as reliable as a transmission source. Distribution systems have a larger geographical foot print, are constructed at a lower overload factor than transmission, and generally have more vegetation caused outages. All of the interconnection points are fused by I&M, therefore non-permanent faults, such as animal contact, will cause a permanent interruption to the Village's service. The addition of a substation and transmission line to the Village of Paw Paw system will remove the I&M dependency, increase reliability to all customers, and increase the number of full capacity ties through use of a substation circuit transfer bus.

The projects proposed in this study are listed in a logical fashion starting with projects affecting large and critical customers (backup circuit ties), the entire circuits (mainline conductor), the need for a reliable transmission line and substation, and ending with projects dealing with equipment of old age and poor condition that needs to be repaired.

Implementation of the recommendations included in this report by Village of Paw Paw will increase capacity of the distribution circuits to maintain current and projected load growth under normal and first contingency conditions, will replace aging infrastructure, and will improve customer reliability.

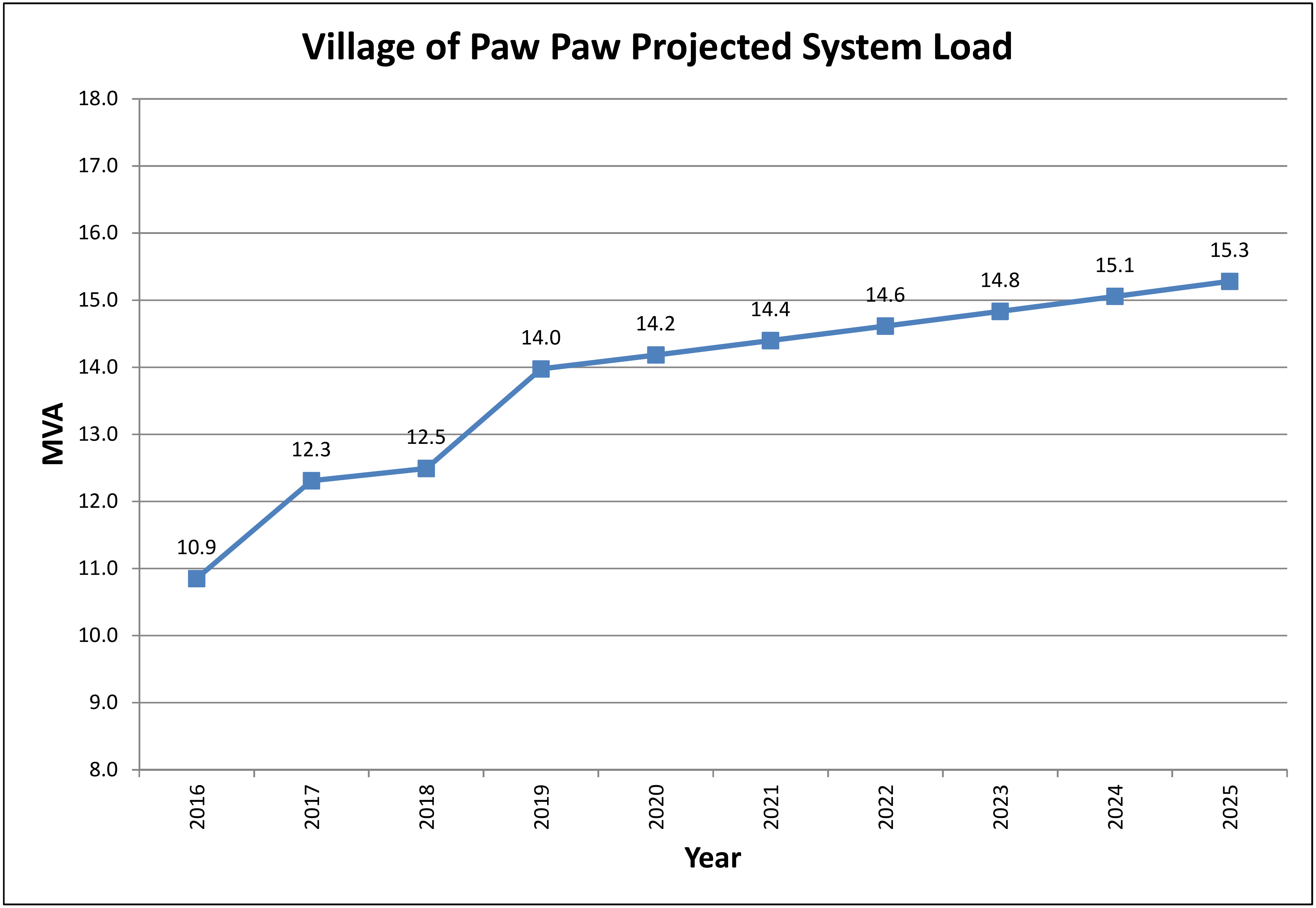
Village of Paw Paw
2018 - 2022 Electric System Projects

Year	Project #	Project Description	Estimated Cost
2018	101	Install approximately 1,250' of #500CU underground cable from a new riser pole on the South Circuit, to be located at the end of Ampey St. Cable would run south and cross under I-94 and continue to the Bronson Lakeview Outpatient Center where it would connect to the existing Walmart Circuit. This will correct the lack of ties to the Walmart Circuit, give the Walmart Circuit another I&M source, and improve reliability to the customers on the Walmart Circuit.	$173,000
2018	102	Rebuild South Circuit overhead line along Commercial Ave. from Lake Blvd. to M-40 (0.25 miles) with #336.4 ACSR. This will increase the capacity and correct the loading issues on this section of line.	$46,250
2018	103	Verify and replace fuses as needed per the recommendations of the 2017 Coordination Study.	$21,150
		2018 Total	$240,400

Year	Project #	Project Description	Estimated Cost
2019	104	Rebuild North Circuit underground from W. Michigan Ave. to Hazen St. with 600' of #500CU. This will increase the capacity of the circuit and correct the loading issues on this section of line.	$86,000
2019	105	Rebuild South Circuit overhead line along M-40 from Berrien St. to Ampey Rd. (0.5 miles) with #336.4 ACSR. This will correct loading issues on the circuit and build a full capacity tie to the Almena Circuit.	$93,750
		2019 Total	$179,750

Village of Paw Paw
2018 - 2022 Electric System Projects

Year	Project #	Project Description	Estimated Cost
2020	106	Rebuild Almena Circuit overhead line along S. Niles St. from E. Berrien St. to the normally open switch, south of Oak St. (0.2 miles) with #336.4 ACSR. This project will create a full capacity tie to the North Circuit that is off an alternate I&M source. This project should be done in conjunction with Project #107.	$40,500
2020	107	Rebuild North Circuit overhead line along S. Gremps St., north to Oak St, east to N. Niles St., and south to the normally open switch tie to the Almena Circuit (0.3 miles) with #336.4 ACSR. This project will create a full capacity tie to the Almena Circuit that is off an alternate I&M source.	$58,000
2020	108	Replace the existing Cooper Kyle "WE" recloser with a G&W Viper with an SEL-351R controller on the North Circuit. The existing recloser is currently loaded to 39.2% and will be loaded to over 40% by 2021. Replacement will keep the circuit recloser operating within the established capacity limits.	$42,500
2020	109	Perform a Thermal Upgrade Study on the North Circuit starting at the circuit recloser and continuing along S. Gremps St. to W. Michigan Ave. This section of line has loading issues based on the #336.4 ACSR being rated at 167°F. Increasing the thermal rating to 212°F will correct the loading issue on this section of line.	$10,500
		2020 Total	$151,500
2021	110	Construction of a new substation with a 12/16/20 MVA power transformer, high and low side relaying, 4 distribution circuit exits, main bus, transfer bus, and control building.	$2,730,000
2021	111	Construction of 1.1 miles of new transmission line commencing at an AEP three terminal tap and ending at the new substation site. Transmission line will be designed using traditional round wood pole, plus two self-supporting laminated wood poles at the new proposed substation site. Conductor will be #477 ACSR on linepost insulators with a static ground wire. Entire transmission line will be designed for double circuit three phase underbuild.	$820,000
		2021 Total	$3,550,000
2022	112	Rebuild South Circuit overhead line along Ampey St. from the underground riser to M-40 (0.6 miles) with #336.4 ACSR. This create a full capacity tie between the North and South Circuits. This tie will correct the low voltage issues that result from tying the two circuits together on the peak day.	$122,500
		2022 Total	$122,500



Village of Paw Paw Projected System Load
MVA
18.0
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
10.9
12.3
12.5
14.0
14.2
14.4
14.6
14.8
15.1
15.3
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
Year

Village of Paw Paw
System Load Flow Study
Protective Equipment & Conductor Loading Limits

Protective Equipment (Reclosers)
Reclosers & Disconnect Switches
Example 560A "WE" Recloser

		Amps	MVA (12.47kV)
Normal	40%	224	5
1st Contigency	80%	448	10
2nd Contigency	100%	560	12

Low Side Equipment & Conductors (12.47kV)
Disconnect Switches, Conductor, UG Equipment
Example ACSR & UG Conductors

		336.4ACSR Amps	1/0ACSR Amps	500kCM 15kV CU	750kCM 15kV CU
Normal	50%	211	99	228	274
1st Contigency	90%	379	178	410	492
2nd Contigency	100%	421	198	456	547

Conductor ratings provided for reference.

*All allowed loading levels are at peak summer load conditions.

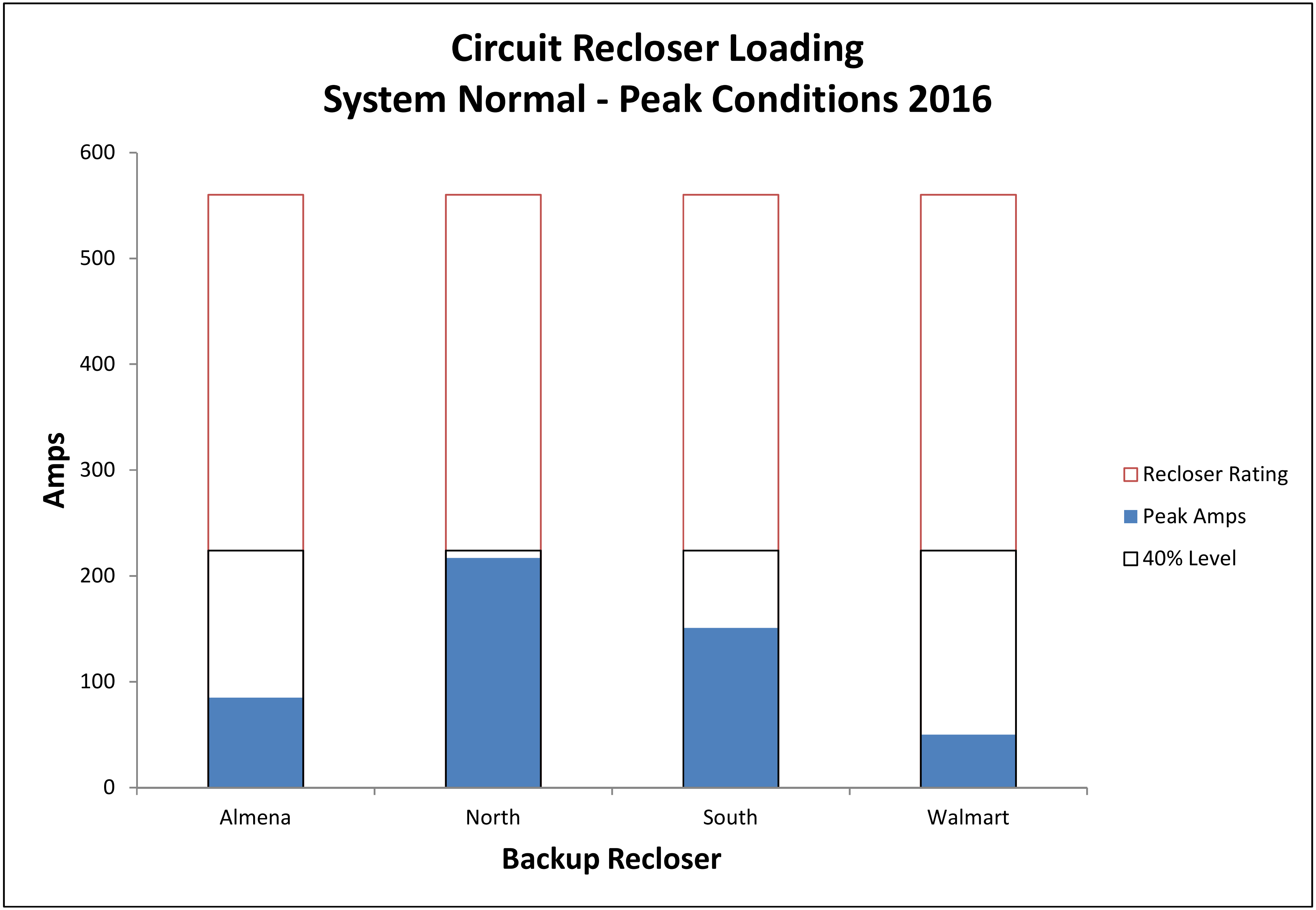
Village of Paw Paw
Conductor Ampacity

ACSR Conductor	Rated Ampacity 120°F	167°F	212°F	50% Rated Ampacity 120°F	167°F	212°F
#4 ACSR 7/1 "Swannate"	46	115	149	23	58	75
#2 ACSR 7/1 "Sparate"	59	153	197	30	77	99
#1/0 ACSR 6/1 "Raven"	73	198	256	37	99	128
#4/0 ACSR 6/1 "Penguin"	96	295	381	48	148	191
#336.4 ACSR 18/1 "Merlin"	119	421	562	60	211	281
#477 ACSR 26/7 "Hawk"	126	533	715	63	267	358
#1/0 Hendrix Black		183	264		92	132
#3/0 Hendrix Black		241	347		121	174
#4/0 Hendrix Black		256	357		128	179
#336 Hendrix Black		370	521		185	261
#336 Hendrix Grey		411	548		206	274
#477 Hendrix Black		457	647		229	324
#477 Hendrix Grey		510	683		255	342

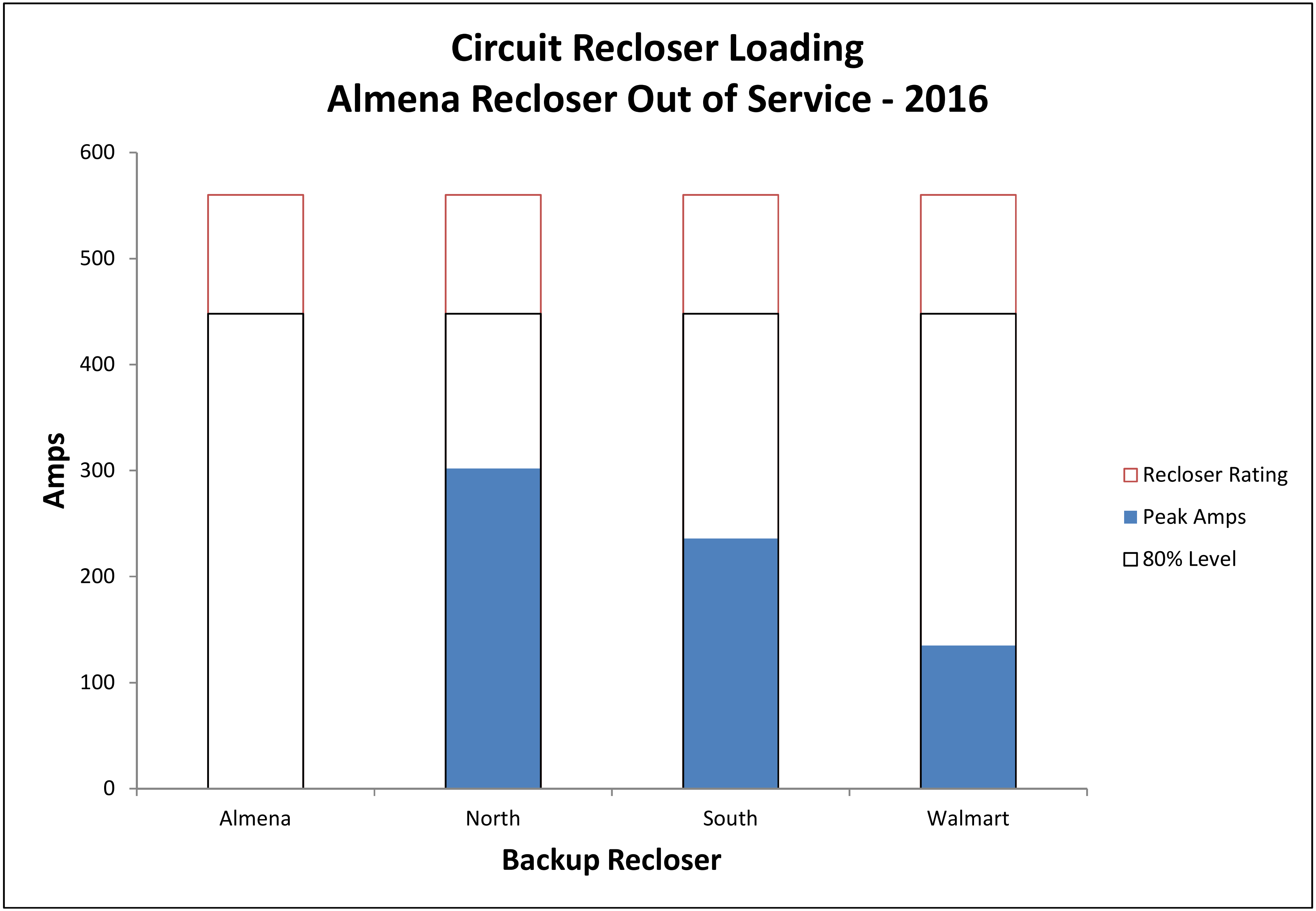
*Ampacities based on 104°F (40°C) Ambient Temperature, 2 ft/sec Wind Speed, Full Sun.

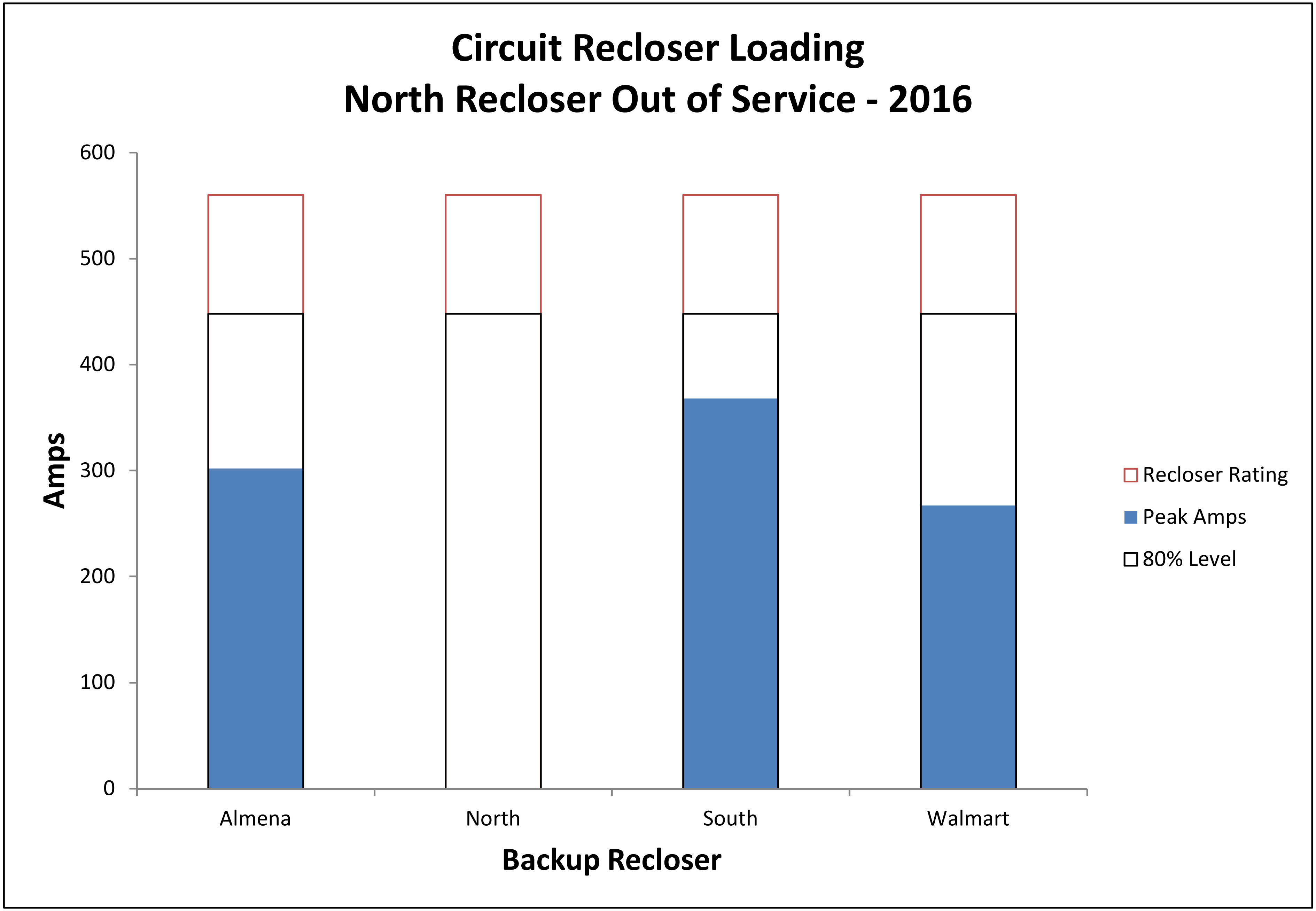
Underground Cable	AL Rated Ampacity Direct Buried	AL Rated Ampacity Buried Ductbank (2-way)	CU Rated Ampacity Direct Buried	CU Rated Ampacity Buried Ductbank (2-way)
#2 15kV Full Neutral	165		215	
#1/0 15kV Full Neutral	215		275	
#4/0 15kV 1/3rd Neutral	250		320	
#4/0 15kV Power Cable		275		350
#350 15kV Power Cable		292		375
#500 15kV 1/3rd Neutral		356		430
#500 15kV Power Cable		378		456
#750 15kV 1/3rd Neutral		427		490
#750 15kV Power Cable		480		547

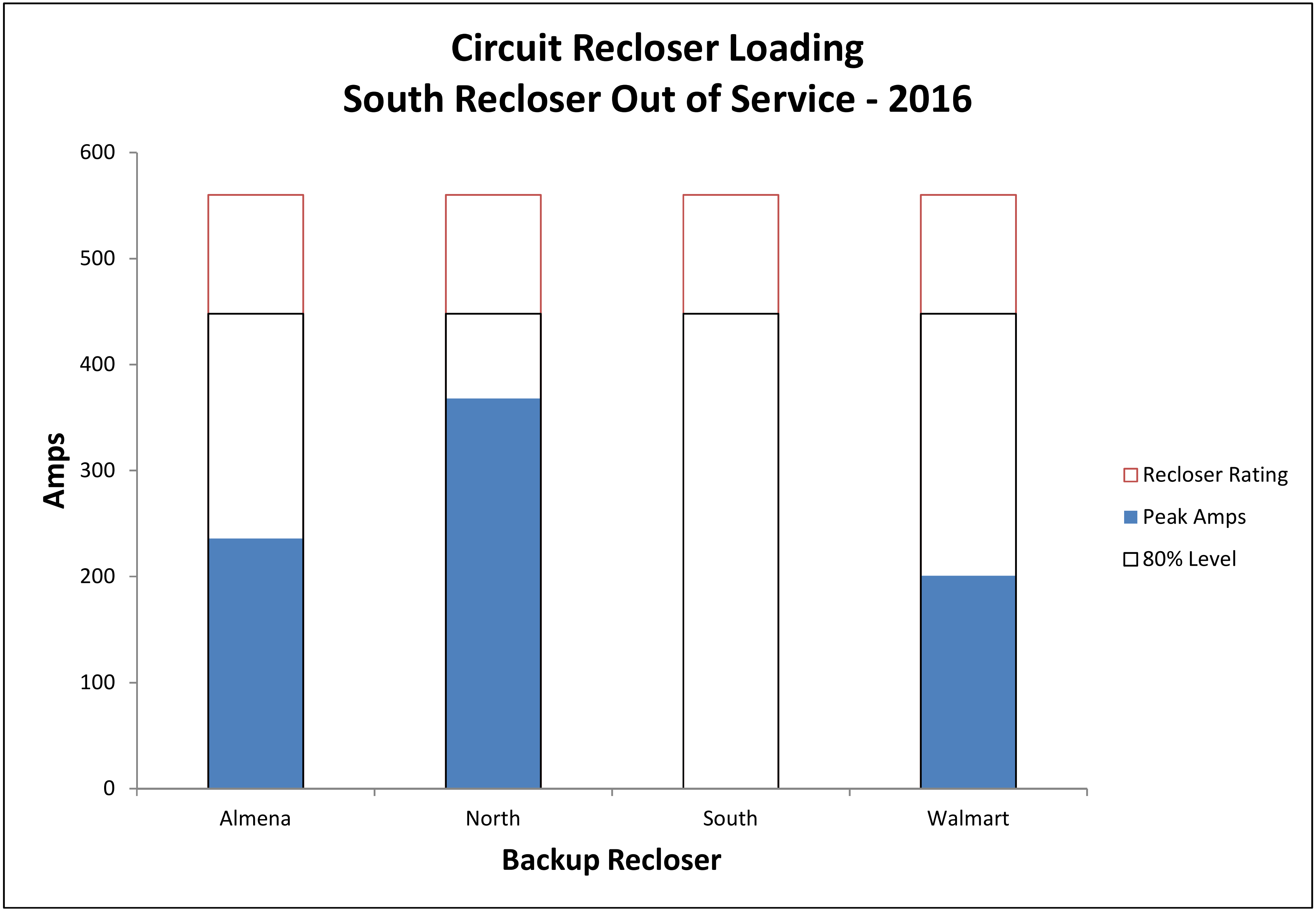
*Ampacities based on 90°C (194°F) conductor temperature, 75% load factor, 20°C (68°F) ambient earth temperature & 90rho soil.

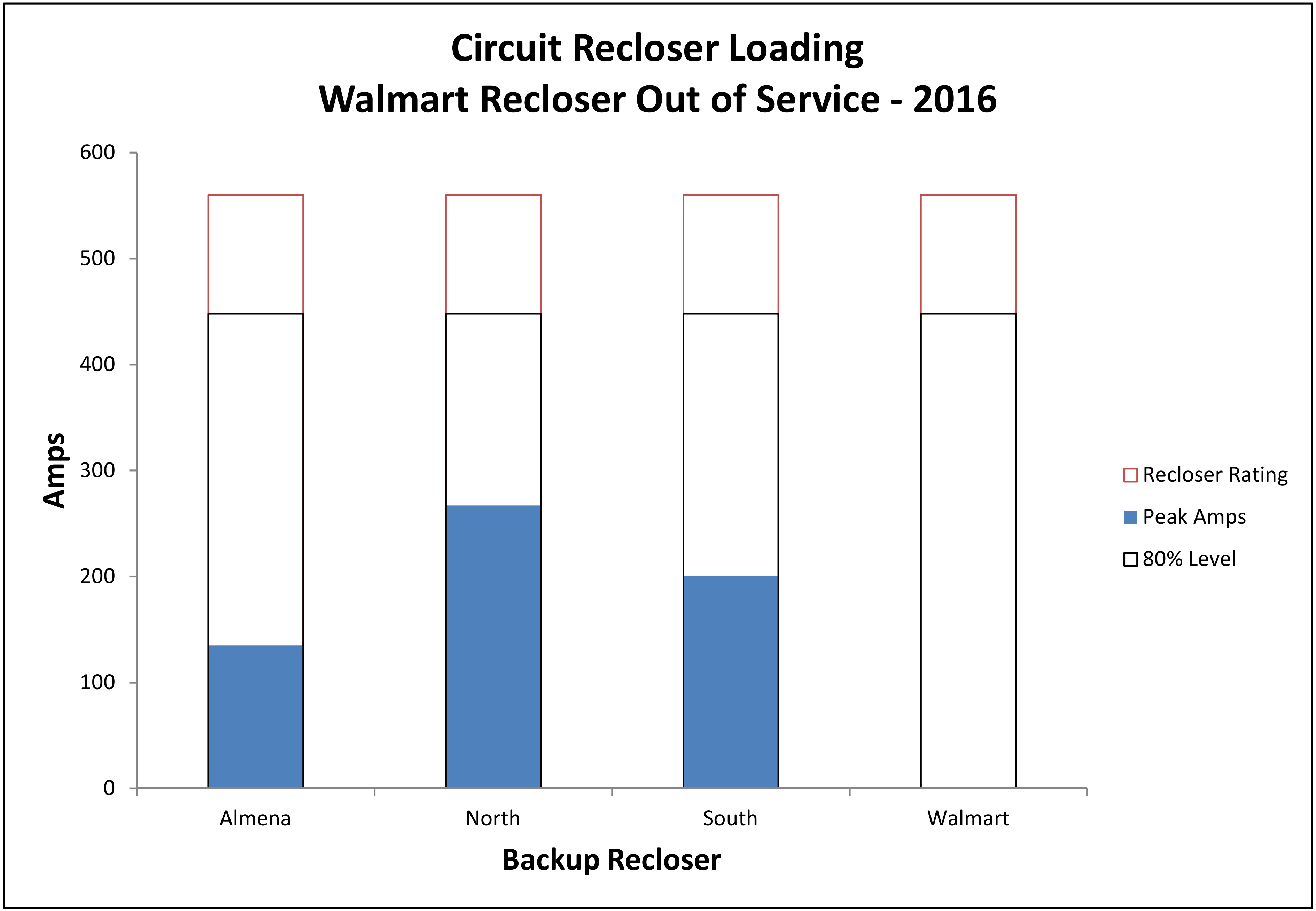


Circuit Recloser Loading
System Normal - Peak Conditions 2016
600
500
400
300
200
100
0
Amps
Almena
North
South
Walmart
Backup Recloser
Recloser Rating
Peak Amps
40% Level

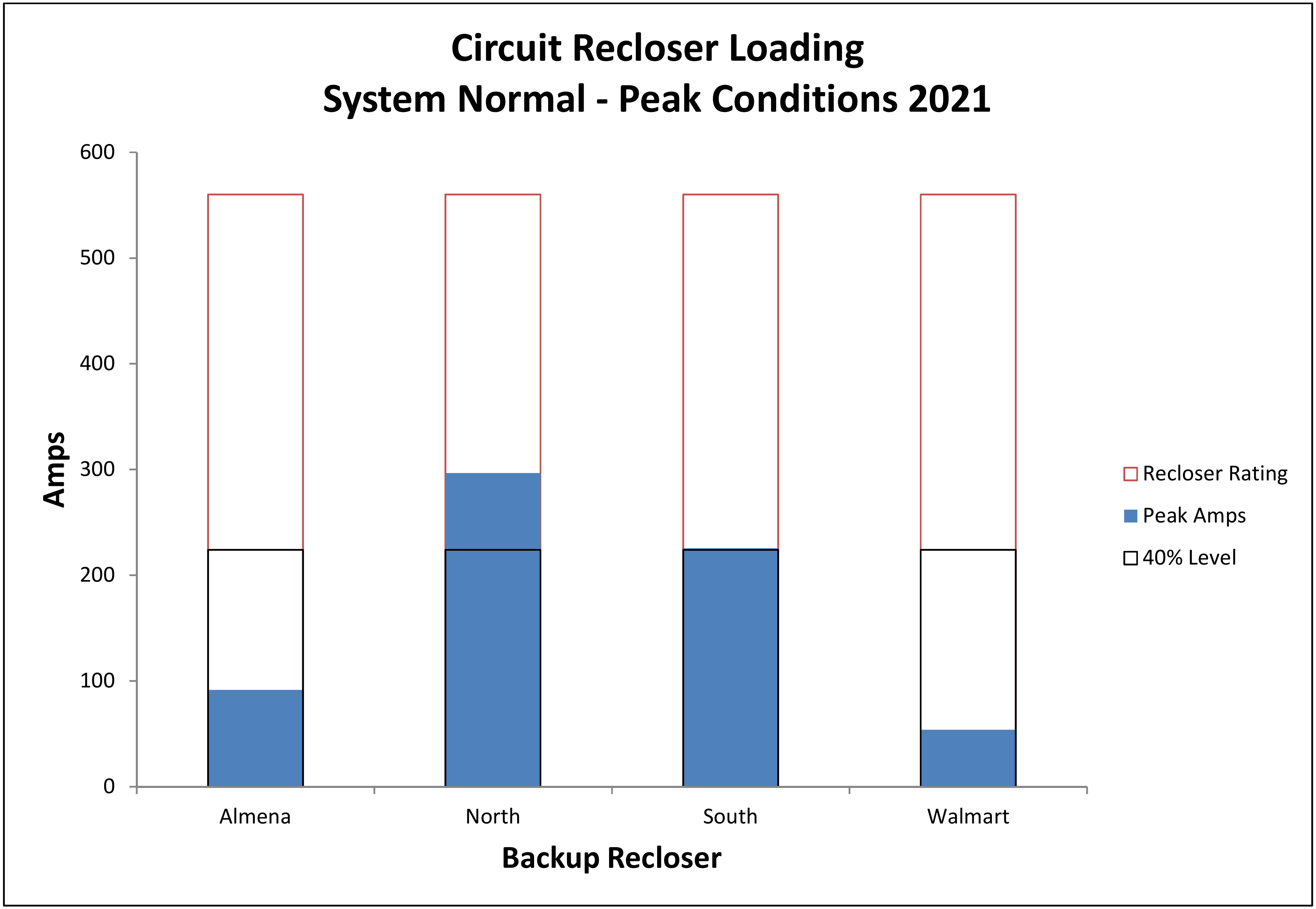

Circuit Recloser Loading
Almena Recloser Out of Service - 2016
Amps
600
500
400
300
200
100
0
Almena
North
South
Walmart
Backup Recloser
Recloser Rating
Peak Amps
80% Level


Circuit Recloser Loading
North Recloser Out of Service - 2016
600
500
400
300
200
100
0
Amps
Almena
North
South
Walmart
Backup Recloser
Recloser Rating
Peak Amps
80% Level

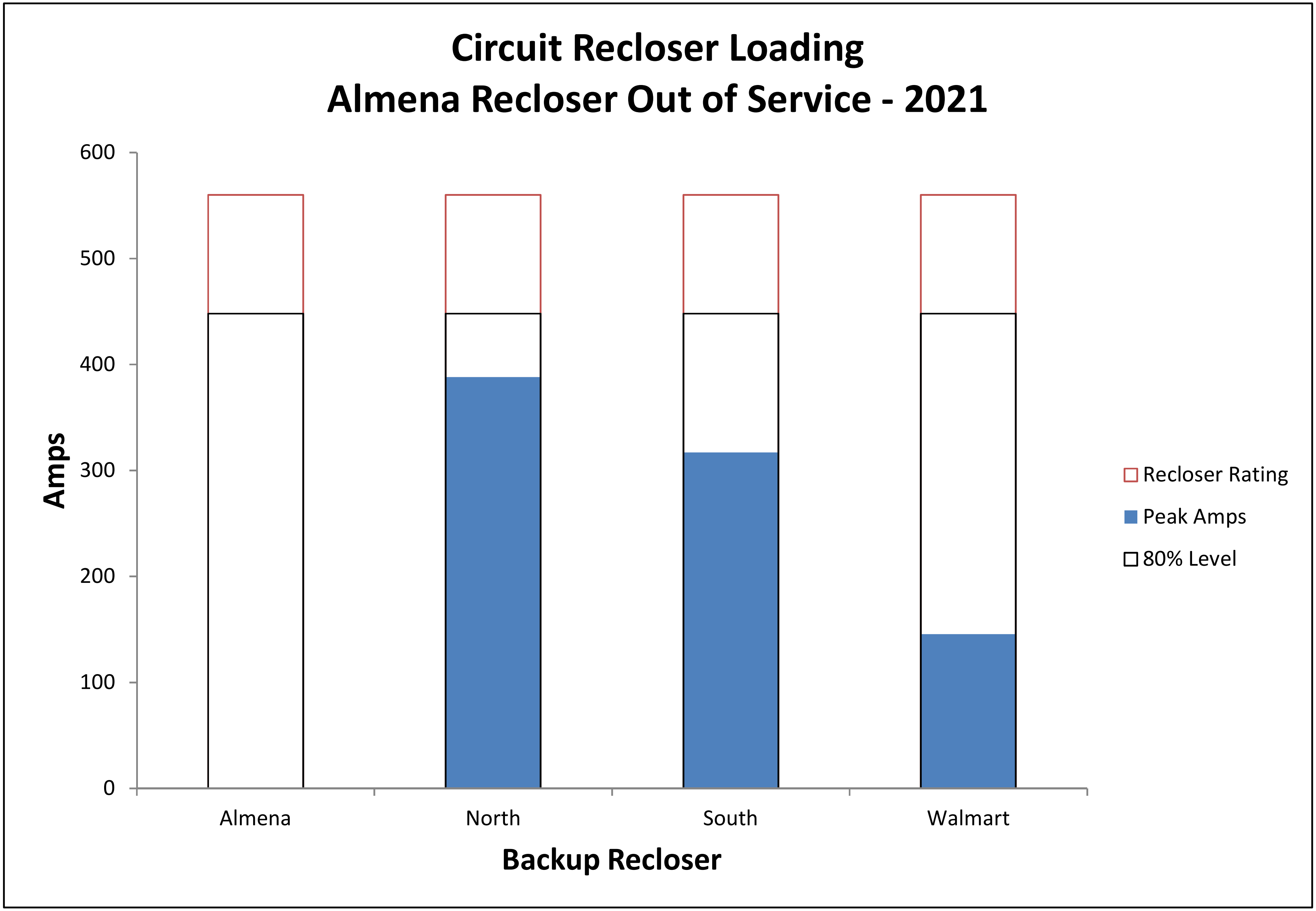

Circuit Recloser Loading
South Recloser Out of Service - 2016
Amps
600
500
400
300
200
100
0
Almena
North
South
Walmart
Backup Recloser
Recloser Rating
Peak Amps
80% Level

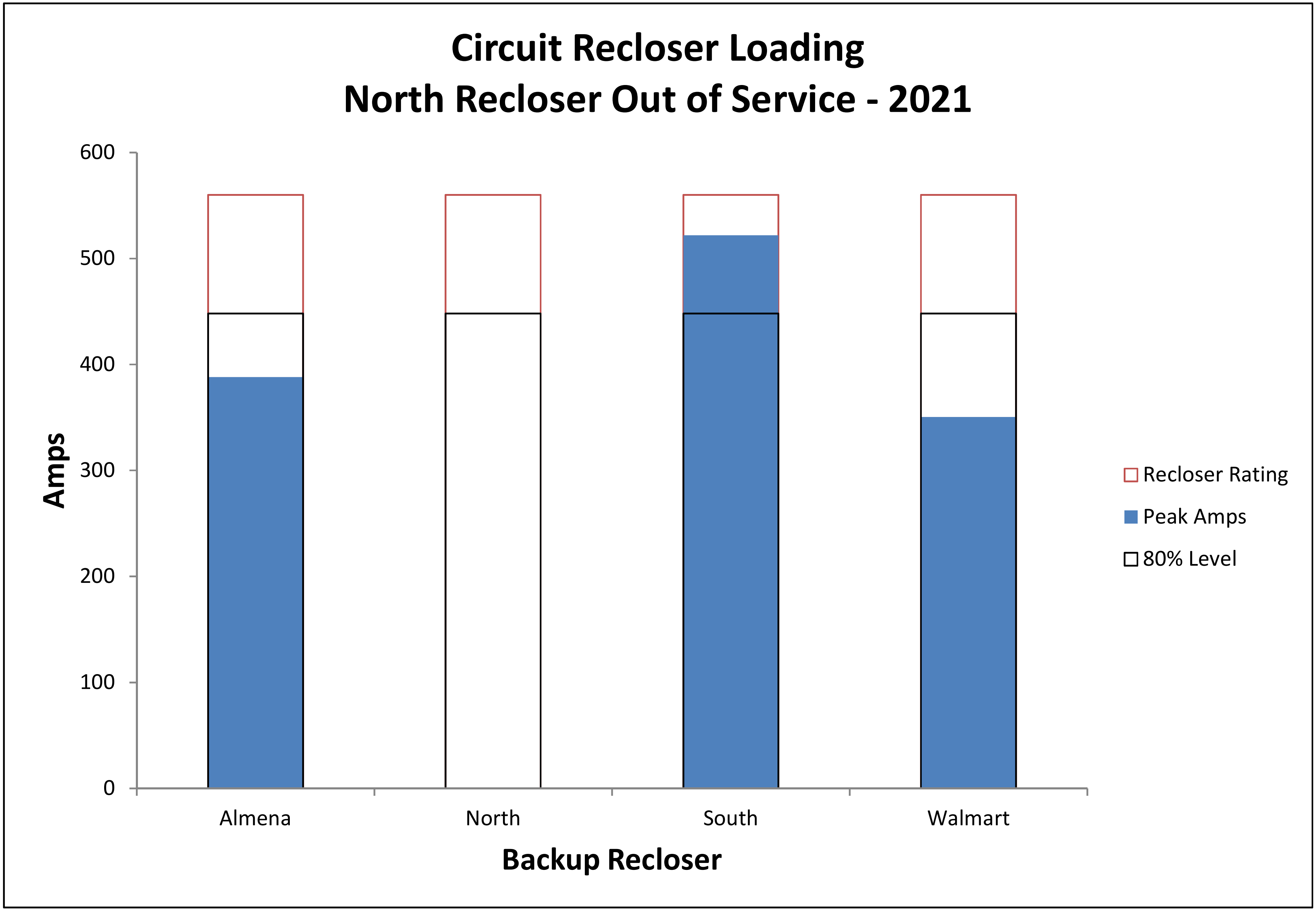


Circuit Recloser Loading
Walmart Recloser Out of Service - 2016
Amps
600
500
400
300
200
100
0
Almena
North
South
Walmart
Backup Recloser
Recloser Rating
Peak Amps
80% Level

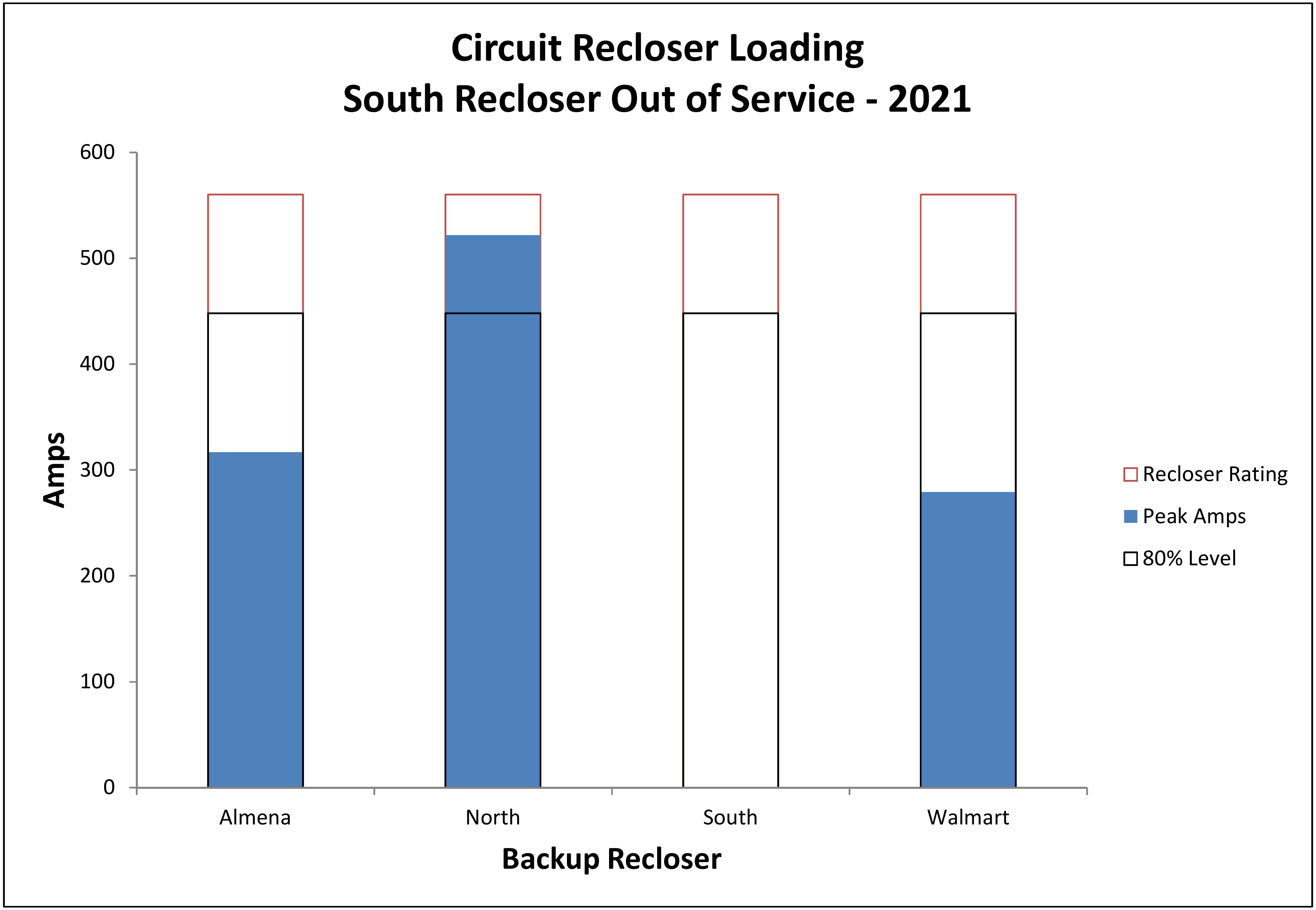


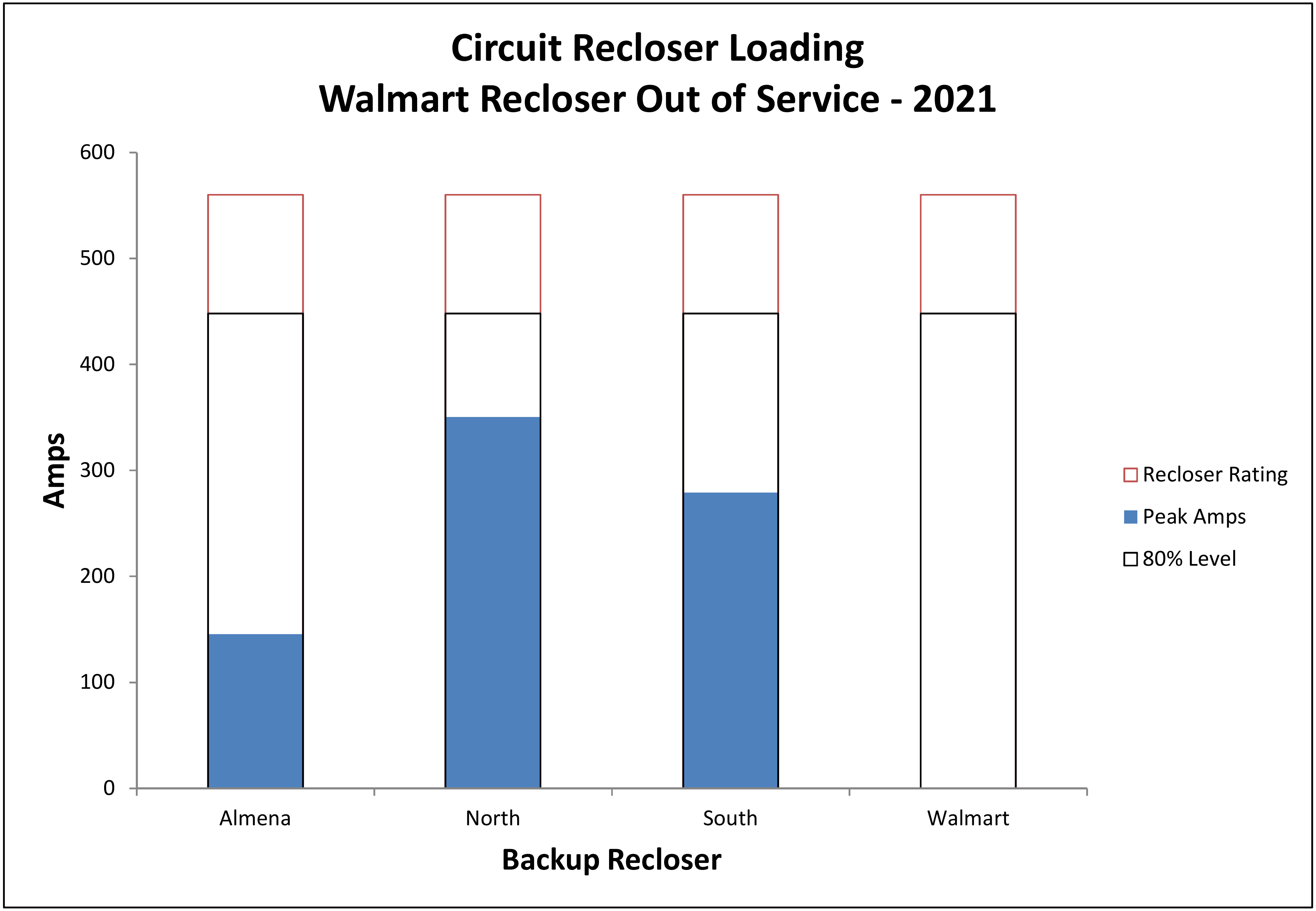
Circuit Recloser Loading
System Normal - Peak Conditions 2021
600
500
400
300
200
100
0
Amps
Almena
North
South
Walmart
Backup Recloser
Recloser Rating
Peak Amps
40% Level

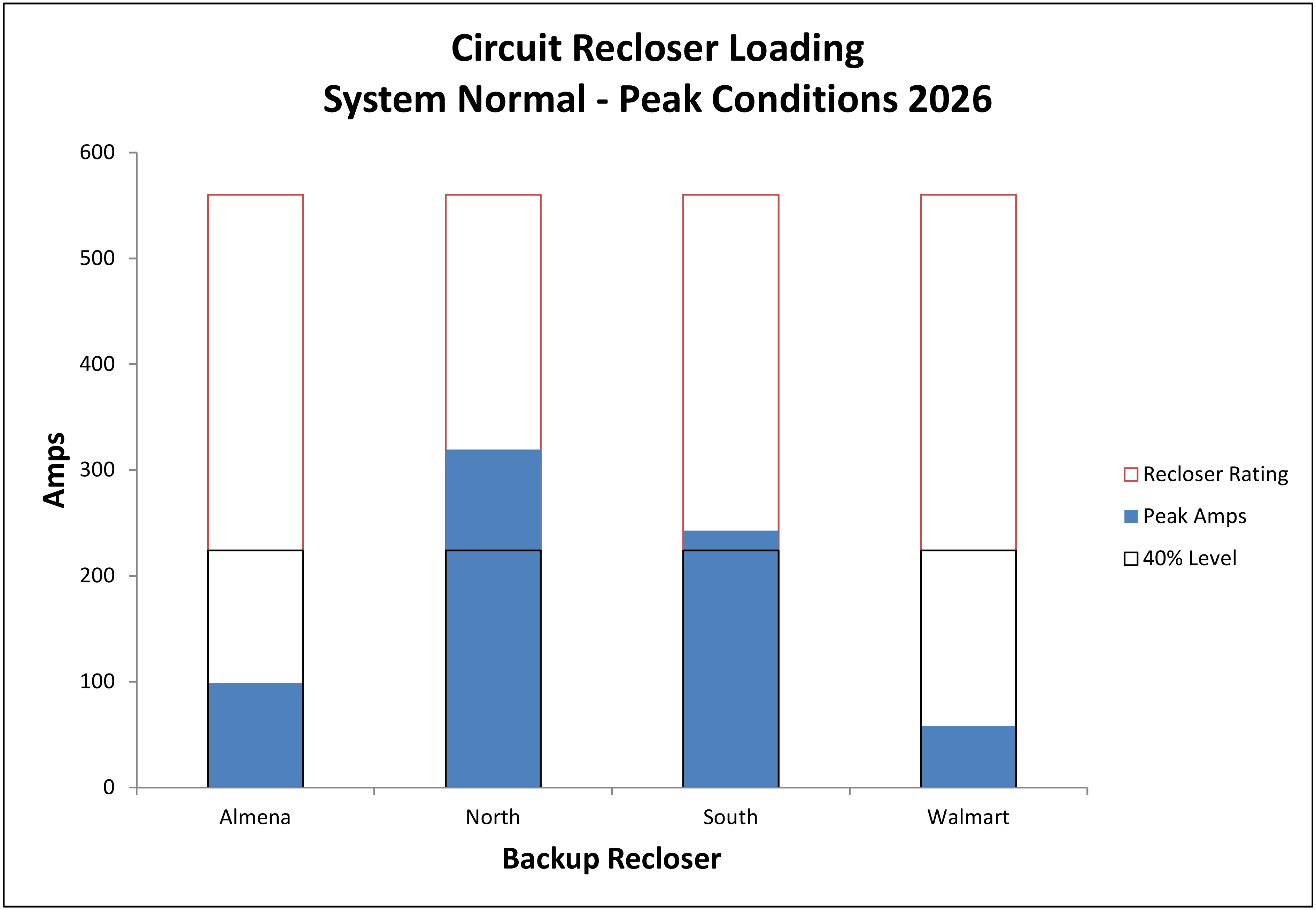

Circuit Recloser Loading
Almena Recloser Out of Service - 2021
600
500
400
300
200
100
0
Amps
Almena
North
South
Walmart
Backup Recloser
Recloser Rating
Peak Amps
80% Level



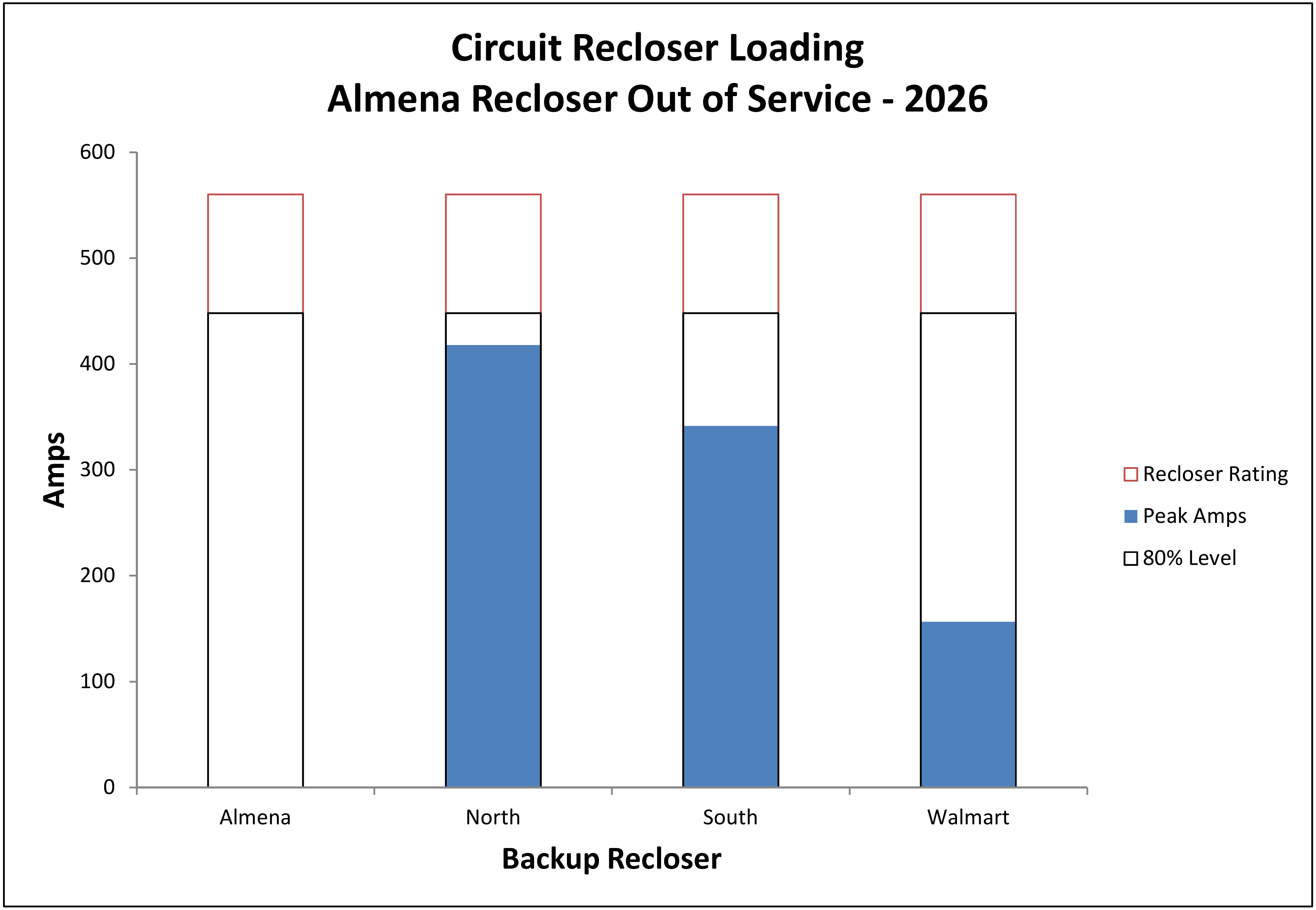
Circuit Recloser Loading
North Recloser Out of Service - 2021
600
500
400
300
200
100
0
Amps
Almena
North
South
Walmart
Backup Recloser
Recloser Rating
Peak Amps
80% Level

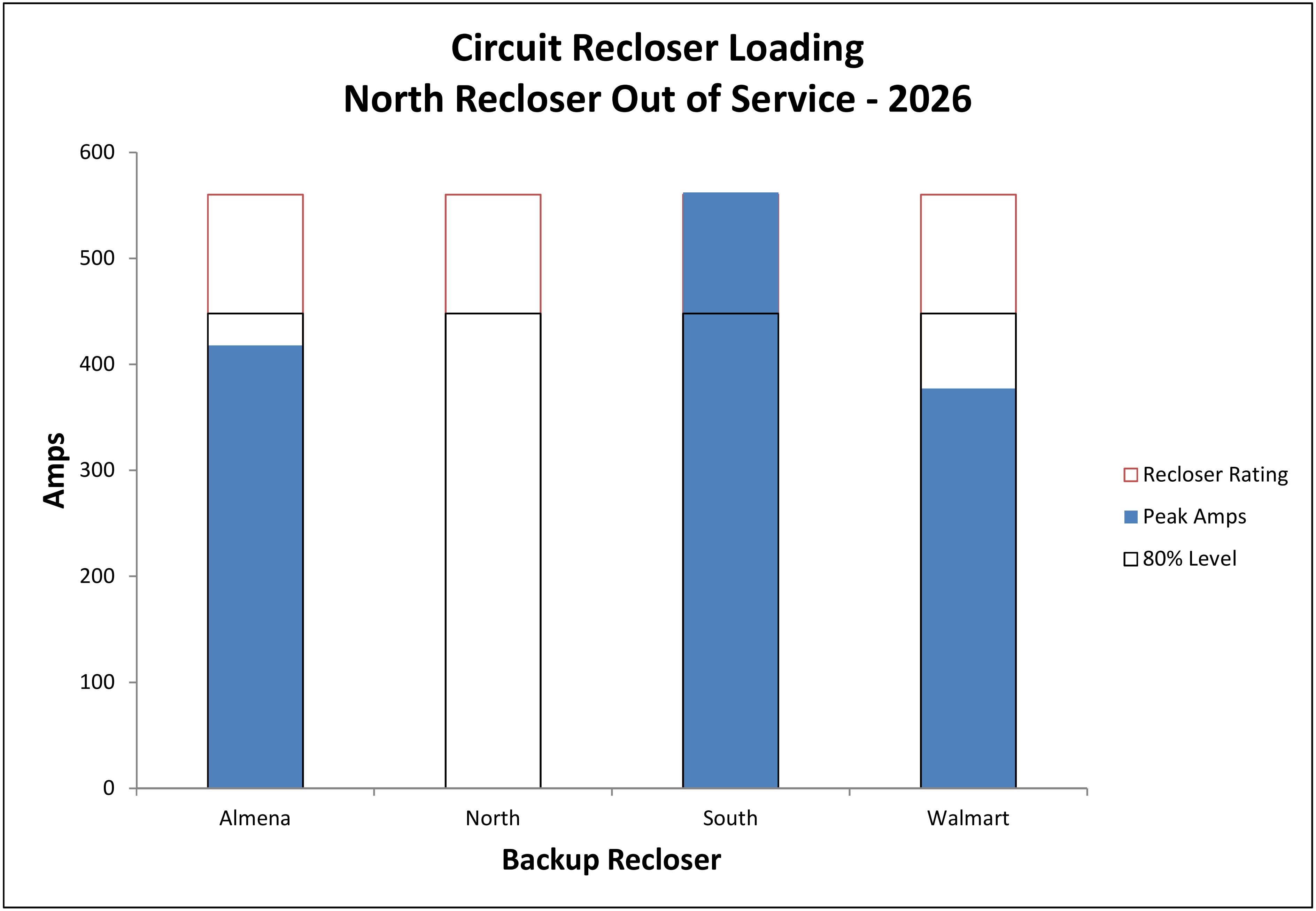

Circuit Recloser Loading
South Recloser Out of Service - 2021
600
500
400
300
200
100
0
Amps
Almena
North
South
Walmart
Backup Recloser
Recloser Rating
Peak Amps
80% Level


Circuit Recloser Loading
Walmart Recloser Out of Service - 2021
600
500
400
300
200
100
0
Amps
Almena
North
South
Walmart
Backup Recloser
Recloser Rating
Peak Amps
80% Level

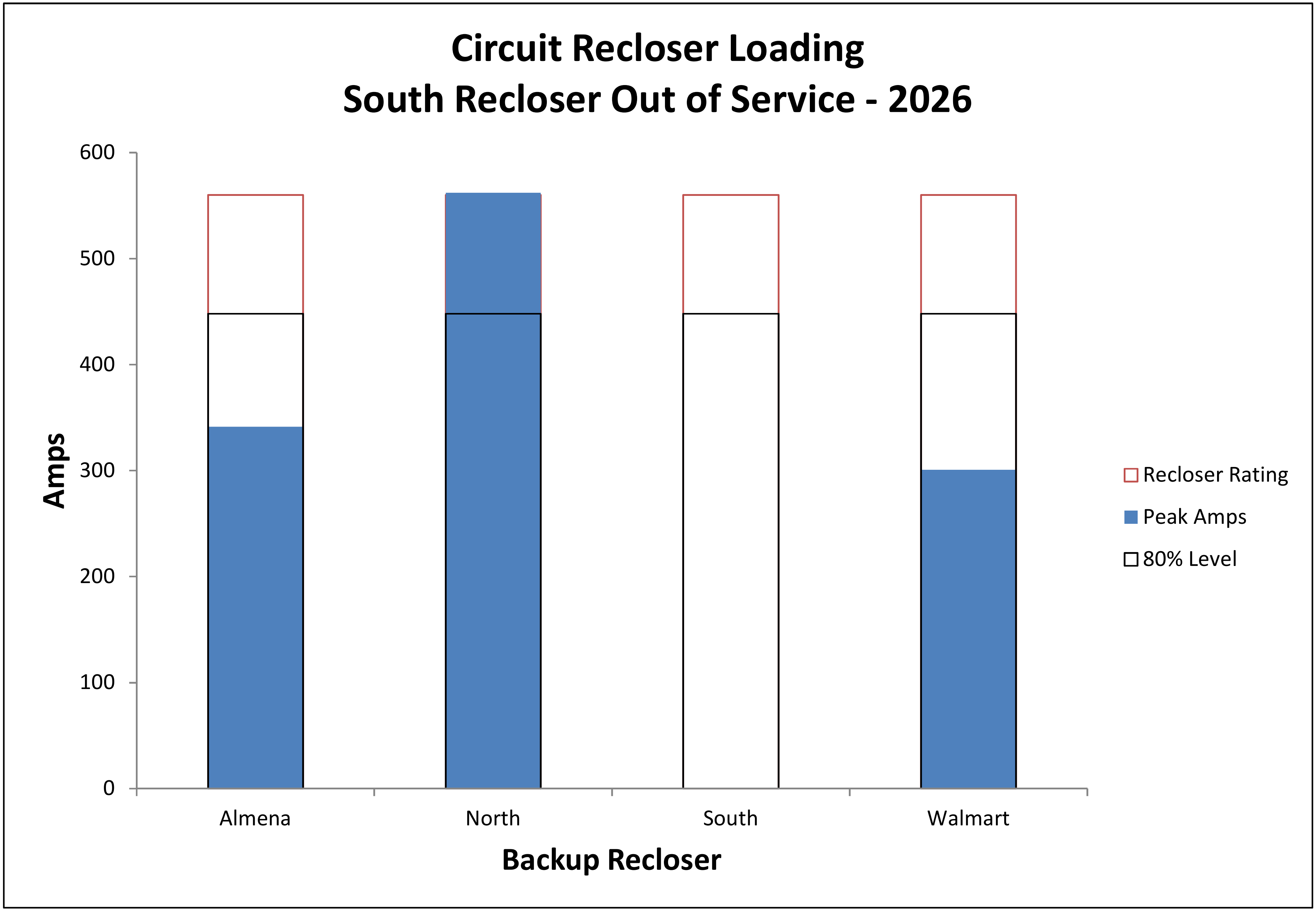


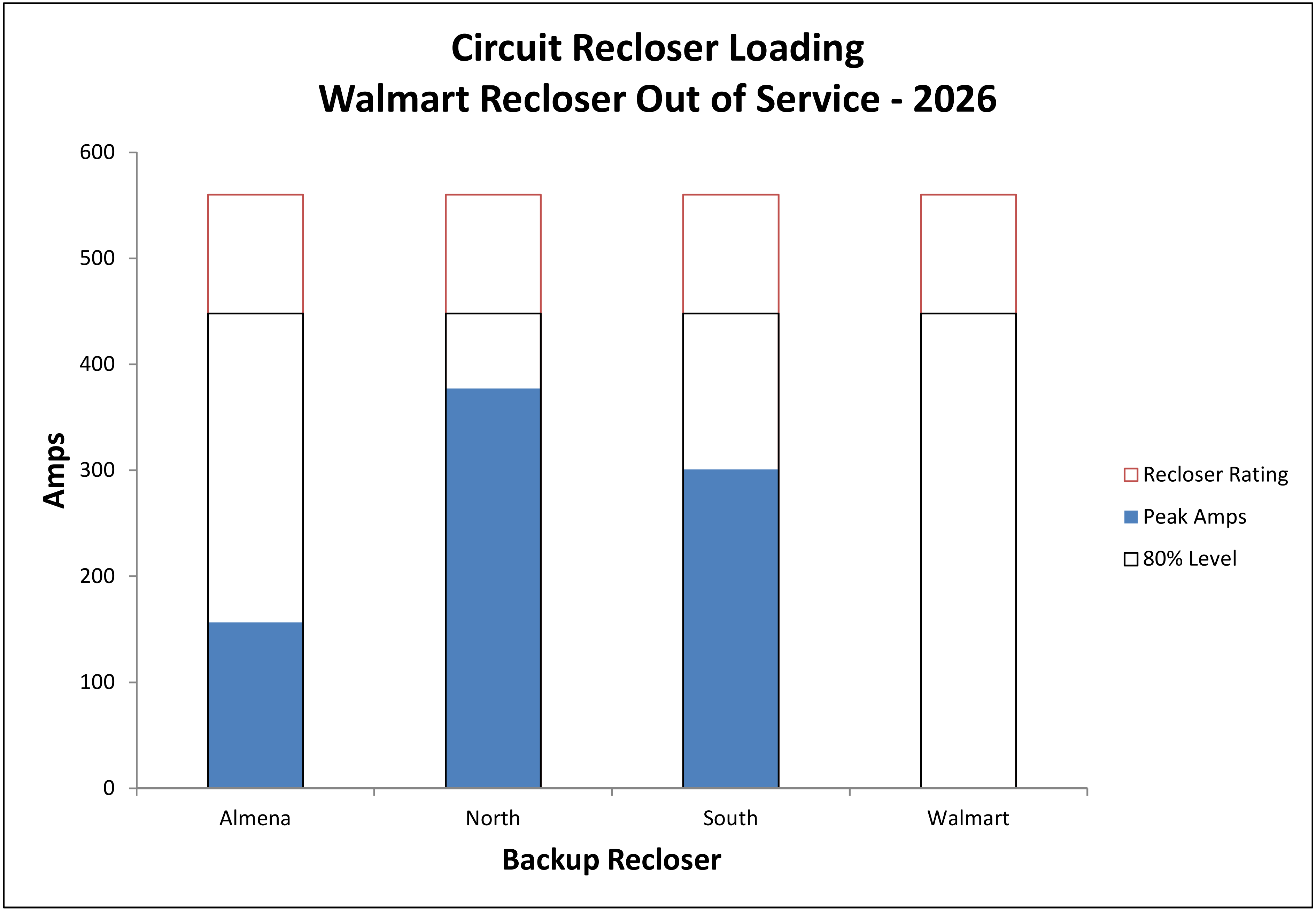
Circuit Recloser Loading
System Normal - Peak Conditions 2026
600
500
400
300
200
100
0
Amps
Almena
North
South
Walmart
Backup Recloser
Recloser Rating
Peak Amps
40% Level

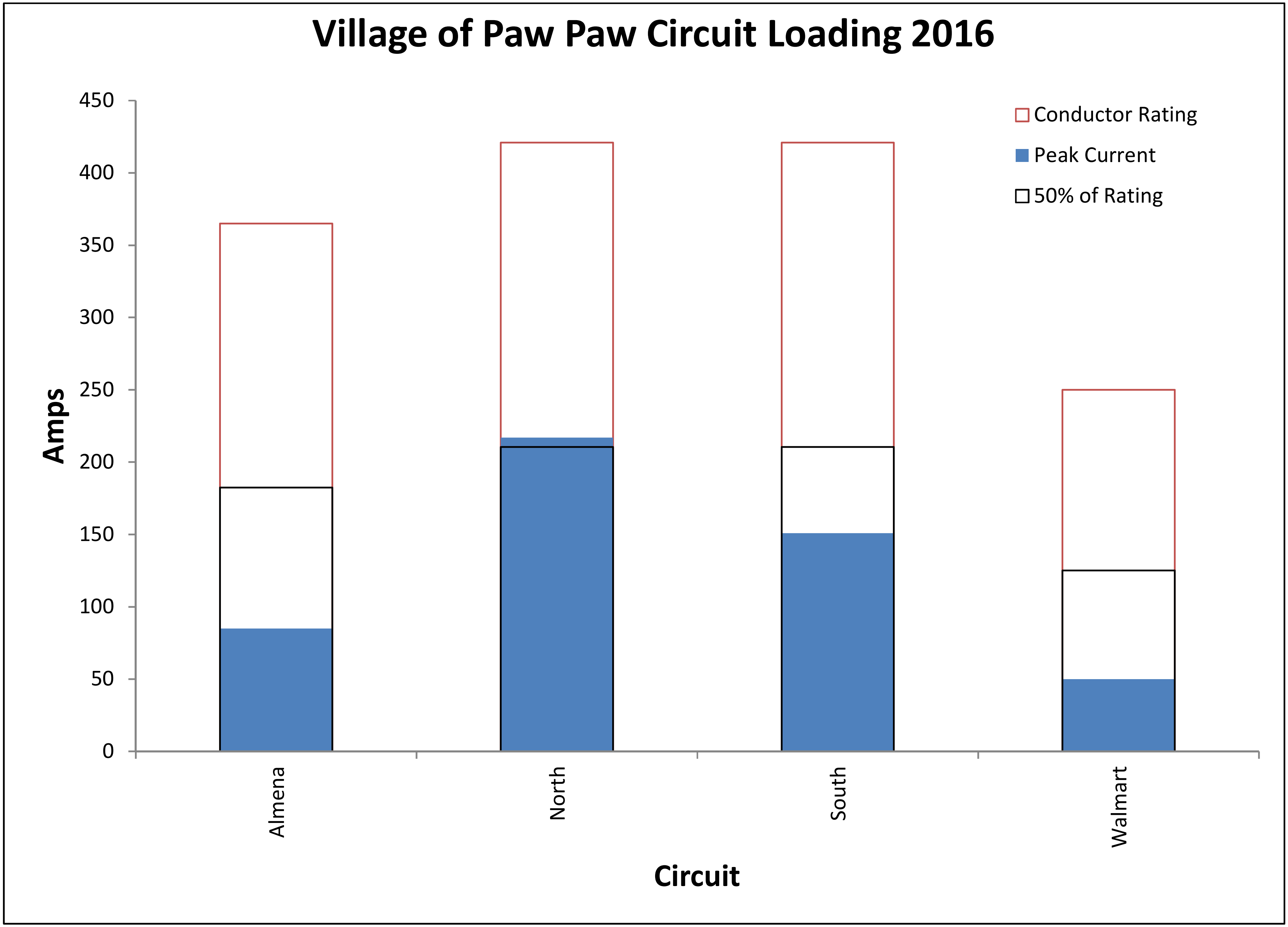

Circuit Recloser Loading
Almena Recloser Out of Service - 2026
Amps
600
500
400
300
200
100
0
Almena
North
South
Walmart
Backup Recloser
Recloser Rating
Peak Amps
80% Level

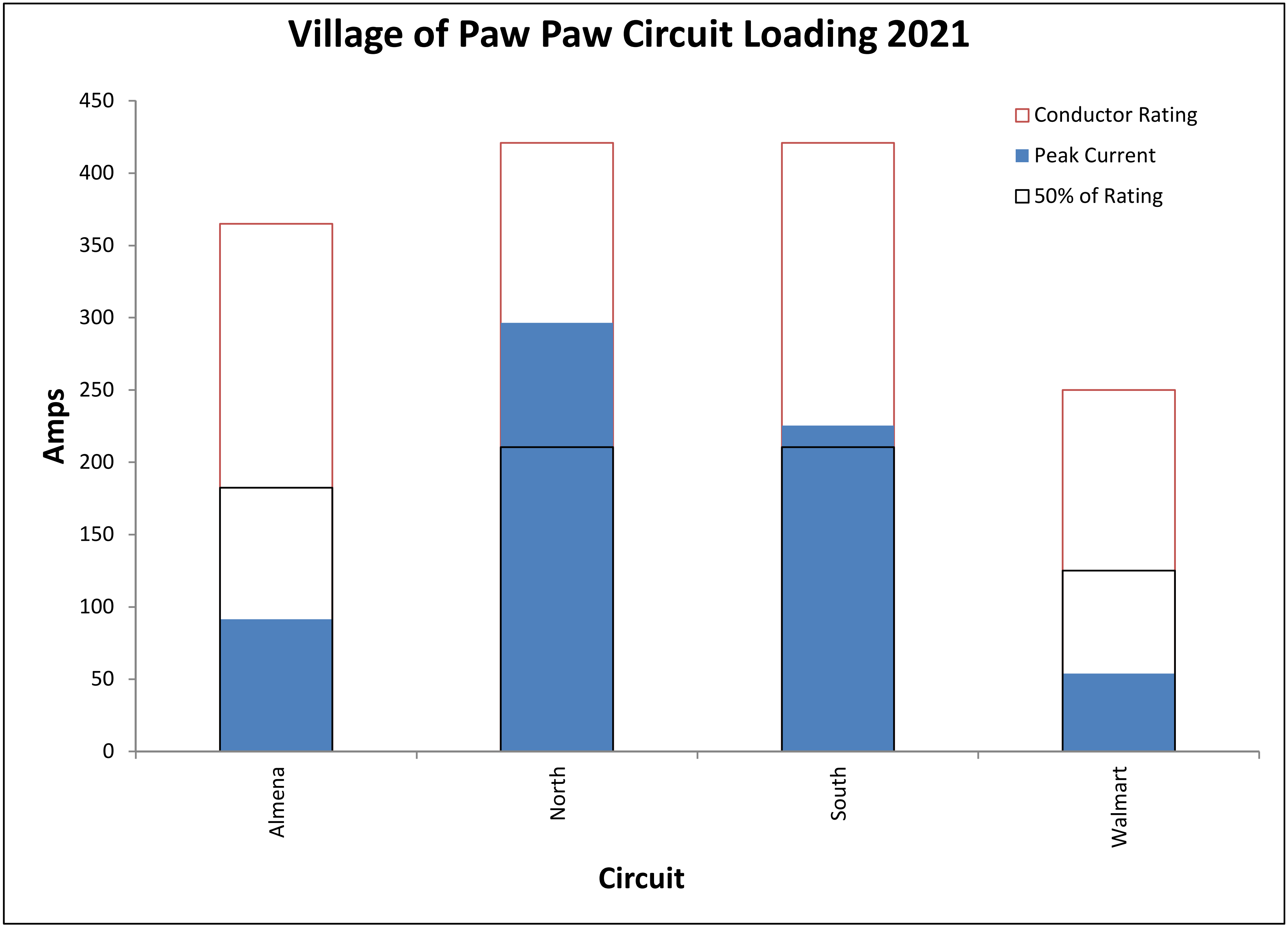


Circuit Recloser Loading
North Recloser Out of Service - 2026
600
500
400
300
200
100
0
Amps
Almena
North
South
Walmart
Backup Recloser
Recloser Rating
Peak Amps
80% Level

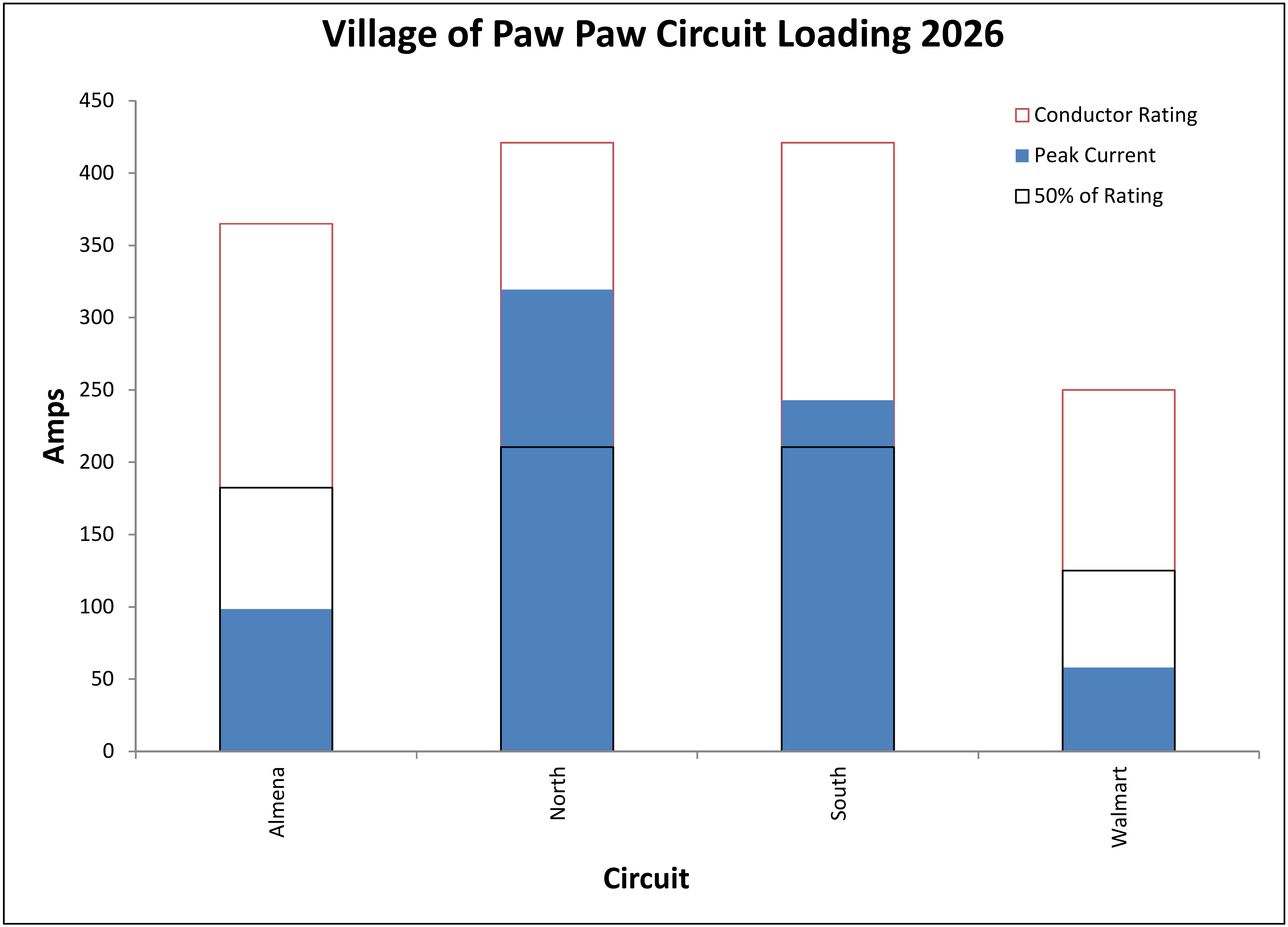

Circuit Recloser Loading
South Recloser Out of Service - 2026
600
500
400
300
200
100
0
Amps
Almena
North
South
Walmart
Backup Recloser
Recloser Rating
Peak Amps
80% Level


Circuit Recloser Loading
Walmart Recloser Out of Service - 2026
Amps
600
500
400
300
200
100
0
Almena
North
South
Walmart
Backup Recloser
Recloser Rating
Peak Amps
80% Level


Village of Paw Paw Circuit Loading 2016
Conductor Rating
Peak Current
50% of Rating
Amps
450
400
350
300
250
200
150
100
50
0
Almena
North
South
Walmart
Circuit



Village of Paw Paw Circuit Loading 2021
Conductor Rating
Peak Current
50% of Rating
Amps
450
400
350
300
250
200
150
100
50
0
Almena
North
South
Walmart
Circuit


Village of Paw Paw Circuit Loading 2026
Conductor Rating
Peak Current
50% of Rating
450
400
350
300
250
200
150
100
50
0
Amps
Almena
North
South
Walmart
Circuit

Village of Paw Paw
System Study & Five Year Plan
Circuit Backup Review

Load Year 2016

Circuit Out-of-Service	Backup Circuit	Total Load	Recloser Capacity	Backup Circuit Conductor Capacity	Notes
Almena	North	302	54%	102%	N. Niles. St., South of Oak St.
Almena	North	302	54%	102%	N. Van Buren St.,South of Elm St.
Almena	North	302	54%	102%	N. Van Buren St., North of E. Mich Ave. (200A Cut-Outs)
Almena	North	302	54%	153%	N. Kalamazoo St., North of Cedar St.
Almena	North	302	54%	153%	Cedar St., East of N. Kalamazoo St.
Almena	South	236	42%	119%	S. Kalamazoo St., South of E. Berrien St.
North	Almena	302	54%	102%	N. Niles. St., South of Oak St.
North	Almena	302	54%	153%	N. Van Buren St.,South of Elm St.
North	Almena	302	54%	83%	N. Van Buren St., North of E. Mich Ave. (200A Cut-Outs)
North	Almena	302	54%	153%	N. Kalamazoo St., North of Cedar St.
North	Almena	302	54%	153%	Cedar St., East of N. Kalamazoo St.
North	South	368	66%	87%	Johnson St., South of Paw Paw Rd.
South	Almena	236	42%	119%	S. Kalamazoo St., South of E. Berrien St.
South	North	368	66%	87%	Johnson St., South of Paw Paw Rd.

Cells highlighted in red represent protective equipment at or above 80% and conductors which would be operating at or above 90% of nameplate rating for these 1st contigency conditions.

Village of Paw Paw
System Study & Five Year Plan
Circuit Backup Review

Load Year 2021

Circuit Out-of-Service	Backup Circuit	Total Load	Recloser Capacity	Backup Circuit Conductor Capacity	Notes
Almena	North	388	69%	132%	N. Niles. St., South of Oak St.
Almena	North	388	69%	132%	N. Van Buren St.,South of Elm St.
Almena	North	388	69%	132%	N. Van Buren St., North of E. Mich Ave. (200A Cut-Outs)
Almena	North	388	69%	196%	N. Kalamazoo St., North of Cedar St.
Almena	North	388	69%	196%	Cedar St., East of N. Kalamazoo St.
Almena	South	317	57%	160%	S. Kalamazoo St., South of E. Berrien St.
North	Almena	388	69%	132%	N. Niles. St., South of Oak St.
North	Almena	388	69%	196%	N. Van Buren St.,South of Elm St.
North	Almena	388	69%	106%	N. Van Buren St., North of E. Mich Ave. (200A Cut-Outs)
North	Almena	388	69%	196%	N. Kalamazoo St., North of Cedar St.
North	Almena	388	69%	196%	Cedar St., East of N. Kalamazoo St.
North	South	522	93%	124%	Johnson St., South of Paw Paw Rd.
South	Almena	317	57%	160%	S. Kalamazoo St., South of E. Berrien St.
South	North	522	93%	124%	Johnson St., South of Paw Paw Rd.

Cells highlighted in red represent protective equipment at or above 80% and conductors which would be operating at or above 90% of nameplate rating for these 1st contigency conditions.

Village of Paw Paw
System Study & Five Year Plan
Circuit Backup Review

Load Year 2026

Circuit Out-of-Service	Backup Circuit	Total Load	Recloser Capacity	Backup Circuit Conductor Capacity	Notes
Almena	North	418	75%	142%	N. Niles. St., South of Oak St.
Almena	North	418	75%	142%	N. Van Buren St.,South of Elm St.
Almena	North	418	75%	142%	N. Van Buren St., North of E. Mich Ave. (200A Cut-Outs)
Almena	North	418	75%	211%	N. Kalamazoo St., North of Cedar St.
Almena	North	418	75%	211%	Cedar St., East of N. Kalamazoo St.
Almena	South	341	61%	172%	S. Kalamazoo St., South of E. Berrien St.
North	Almena	418	75%	142%	N. Niles. St., South of Oak St.
North	Almena	418	75%	211%	N. Van Buren St.,South of Elm St.
North	Almena	418	75%	115%	N. Van Buren St., North of E. Mich Ave. (200A Cut-Outs)
North	Almena	418	75%	211%	N. Kalamazoo St., North of Cedar St.
North	Almena	418	75%	211%	Cedar St., East of N. Kalamazoo St.
North	South	562	100%	134%	Johnson St., South of Paw Paw Rd.
South	Almena	341	61%	172%	S. Kalamazoo St., South of E. Berrien St.
South	North	562	100%	134%	Johnson St., South of Paw Paw Rd.

Cells highlighted in red represent protective equipment at or above 80% and conductors which would be operating at or above 90% of nameplate rating for these 1st contigency conditions.

VILLAGE OF PAW PAW
CRITICAL AND LARGE LOAD CUSTOMERS
SYSTEM STUDY

Customer	Circuit	Backup Circuit Ties[1]	Ties to Alternate I&M Interconnections[2]	Existing Reliability[3]	Post Project Reliability[4]
Village of Paw Paw Offices	North	Yes	No	Moderate	Very High
Public Service Department	Almena	No	Yes	Moderate	Very High
Paw Paw Police Department	Almena	No	Yes	Moderate	Very High
Michigan State Police	North	Yes	No	Moderate	Very High
Van Buren County Offices	Almena	No	Yes	Moderate	Very High
Van Buren County Jail	Almena	No	Yes	Moderate	Very High
Paw Paw Fire Department	Almena	No	Yes	Moderate	Very High
Paw Paw Middle School	North	Yes	No	Moderate	Very High
Water Plant	North	Yes	No	Moderate	Very High
Bronson Lake View Hospital	North	Yes	No	Moderate	Very High
Bronson Lake Outpatient	Walmart	No	No	Very Low	Very High
Family Fare	South	Yes	No	Moderate	Very High
Wal-mart	Walmart	No	No	Very Low	Very High
St. Julian Winery	South	Yes	No	Moderate	Very High

[1] Backup circuit ties were evaluated under peak loading 2016 critiria

[2] Ties to alternate I&M interconnection points were evaluated using in the field tie switches

[3] Existing Reliability is based off the current backup ties and ties to alternate I&M interconnections

[4] Post Project Reliability is based off the backup tie and ties to alternate I&M interconnections after all capital projects have been completed, with the exception of substation and transmission projects

VILLAGE OF PAW PAW
SYSTEM STUDY
CRITICAL ASSETS

Assest Description	Location	Number of Customers Impacted	Large/Critical Customers Impacted	Community Impact	Single-point Failure	Maintenance History/Reliability	Probability of Failure	Safety Impact	Spare Lead Time	Replacement Value	Utilization Rate	Rating
Almena Ckt Recloser	Berrien St "Substation"	10	10	10	10	0	5	8	10	8	10	81
North Ckt Recloser	Johnson Rd Connection Point	10	10	2	0	0	5	8	10	8	10	63
South Ckt Recloser	Johnson Rd Connection Point	10	10	2	0	0	5	8	10	8	10	63
Walmart Recloser	Family Fare Connetion Point	10	10	10	10	0	5	8	10	8	10	81
Capacitor Banks	Various	1	0	0	0	0	10	10	10	2	10	43
Switches	Various	1	1	1	0	0	4	6	4	4	10	31
3ph Mainline (Almena Ckt)	Mainline Section of Circuit	10	10	10	8	0	2	4	2	9	10	65
3ph Mainline (North Ckt)	Mainline Section of Circuit	10	10	10	3	0	2	4	2	9	10	60
3ph Mainline (South CKt)	Mainline Section of Circuit	10	10	10	3	0	2	4	2	9	10	60
3ph Mainline (Walmart Ckt)	Mainline Section of Circuit	10	10	10	10	0	2	4	2	9	10	67
3ph Leads (Almena Ckt)	3-phase Leads on Circuit	6	10	4	10	0	2	4	2	7	10	55
3ph Leads (North Ckt)	3-phase Leads on Circuit	6	10	4	10	0	2	4	2	7	10	55
3ph Leads (South CKt)	3-phase Leads on Circuit	6	10	4	10	0	2	4	2	7	10	55
3ph Leads (Walmart Ckt)	3-phase Leads on Circuit	6	10	4	10	0	2	4	2	7	10	55
1ph Taps (Almena Ckt)	1-phase Taps on Circuit	2	0	1	10	0	2	4	2	5	10	36
1ph Taps (North Ckt)	1-phase Taps on Circuit	2	0	1	10	0	2	4	2	5	10	36
1ph Taps (South CKt)	1-phase Taps on Circuit	2	0	1	10	0	2	4	2	5	10	36
1ph Taps (Walmart Ckt)	1-phase Taps on Circuit	2	0	1	10	0	2	4	2	5	10	36
Hospital Transformer	Bronson Lakevview Hospital	1	10	10	10	0	3	5	8	8	10	65
Outpatient Transformer	Health Parkway	1	10	8	10	0	3	5	8	7	10	62
Walmart Transformer	Walmart (M-40)	1	10	8	10	0	3	5	8	7	10	62
Middle School Transformer	Paw Paw Middle School	1	10	8	10	0	3	5	4	6	10	57
Elementary School Transformer	Paw Paw Elementary School	1	0	8	10	0	3	5	4	6	10	47
Family Fare Transformer	Family Fare (Kalamazoo St)	1	10	7	10	0	3	5	4	5	10	55

VILLAGE OF PAW PAW
SYSTEM STUDY
CRITICAL ASSETS

Assest Description	Location	Number of Customers Impacted	Large/Critical Customers Impacted	Community Impact	Single-point Failure	Maintenance History/Reliability	Probability of Failure	Safety Impact	Spare Lead Time	Replacement Value	Utilization Rate	Rating
St. Julian Transformer	Kalamazoo St	1	10	5	10	0	3	5	4	5	10	53
St. Julian Transformer	Kalamazoo St	1	10	5	10	0	3	5	4	5	10	53
Industrial Transformer	Factory St	1	0	5	10	0	3	5	4	5	10	43

ENG.	MPM		
DR	KMW		
CK	MPM		
APP	MPM	04/07/2017	FINAL STUDY
		03/10/2017	DRAFT STUDY
		DATE	ISSUED FOR

GRP Engineering, Inc.

PETOSKEY, MICHIGAN, 231-439-9683
GRAND RAPIDS, MICHIGAN, 616-942-7183

VILLAGE OF PAW PAW

SYSTEM STUDY

PAW PAW, MICHIGAN

SYSTEM CIRCUIT MAP

PROJECT NUMBER
15-0746.03

DRAWING NUMBER
CKT

LEGEND

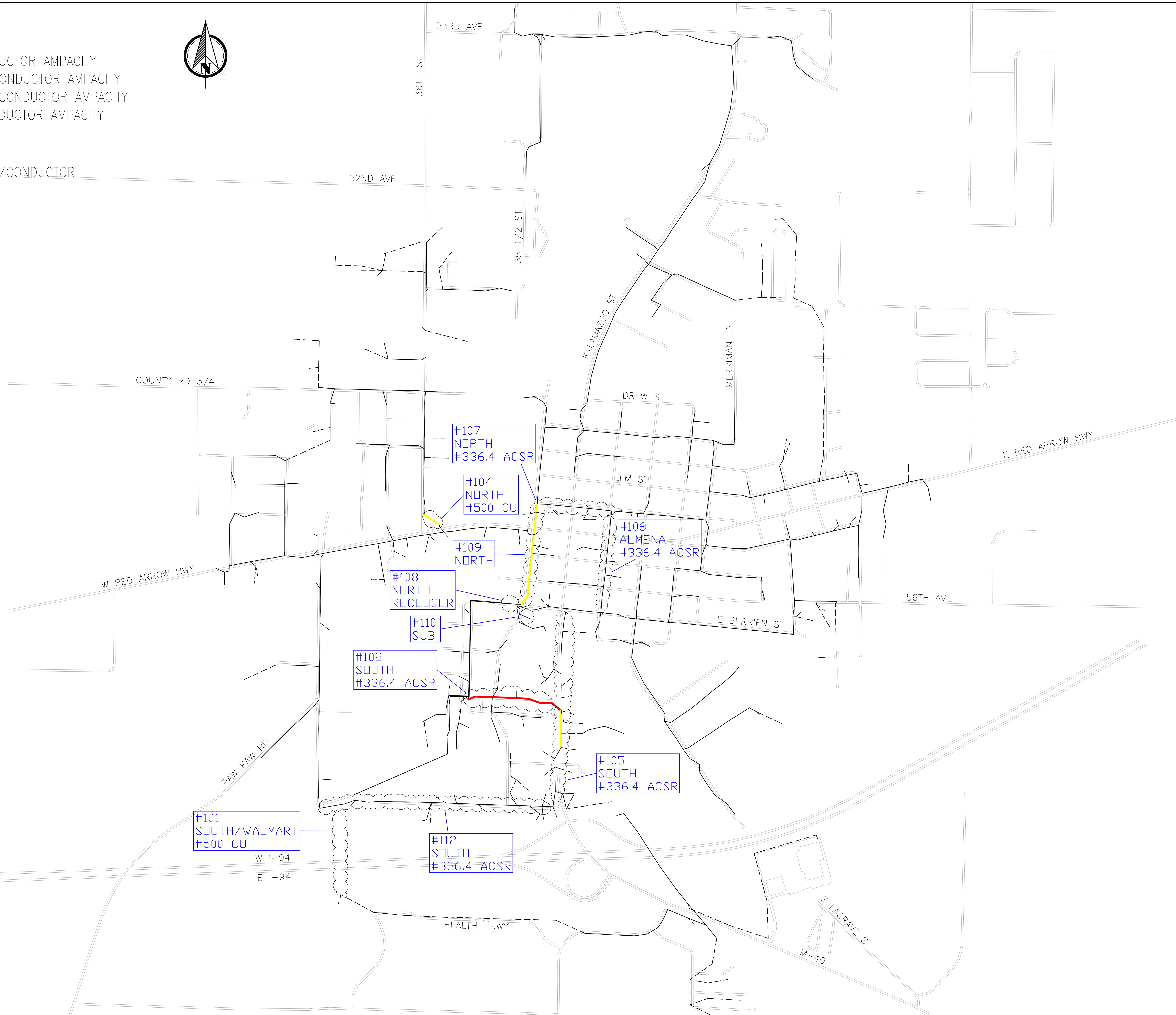
- <50% RATED CONDUCTOR AMPACITY (black line)
- 50%-80% RATED CONDUCTOR AMPACITY (yellow line)
- 80%-100% RATED CONDUCTOR AMPACITY (red line)
- >100% RATED CONDUCTOR AMPACITY (orange line)

#___	PROJECT NUMBER
XXX-X	CIRCUIT
#____	PROPOSED CHANGE/CONDUCTOR

NOTES:

1. NORMAL SYSTEM STATUS
   - ALL CIRCUITS AND SWITCHES IN NORMAL STATE
   - CAPACITOR BANKS SWITCHED ON
   - ALL VOLTAGE REGULATORS OPERATING
2. CONDUCTOR AMPACITY RATING BASED ON
   - 104°F AMBIENT TEMPERATURE
   - 167°F CONDUCTOR TEMPERATURE
   - 2 FT/SEC WIND SPEED
3. CIRCUITS LOADS BASED ON 2015 PEAK.

PROJECT LIMIT



ENG.	MPM
DR	KMW
CK	MPM
APP	MPM

DATE	ISSUED FOR
08-14-2017	PROJECT NUMBER REVISION
04-07-2017	FINAL STUDY
03/10/2017	DRAFT STUDY

GRP Engineering, Inc.
PETOSKEY, MICHIGAN, 231-439-9683
GRAND RAPIDS, MICHIGAN, 616-942-7183

VILLAGE OF PAW PAW

SYSTEM STUDY

PAW PAW, MICHIGAN

CONDUCTOR CAPACITY AND PROPOSED PROJECTS

PROJECT NUMBER	DRAWING NUMBER
15-0746.03	CAP