Electrical Distribution System Feeder Reconfiguration to System Reliability

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Abstract: This study evaluated the effect of reconfiguration of Astron and L&S 13.8 KV feeders of Angeles Power Incorporated (API) - Angeles Electric Corporation (AEC) substation, for the improvement of operation ability of the system and consistency of power supply of Bacolor load or Pampanga Electric Cooperative II. The three-phase balanced load flow analysis has been performed for different cases to assess the worth of reconfiguration. There are four cases that were presented for comparative analysis that were involved in the study. Line flow, node voltage, and system losses were analyzed before and after the reconfiguration based on off-peak and peak conditions. It also quantifies the allocated line losses of Bacolor, which will be carried out by API instead on AEC. Based on the results of the study, conclusions were created and possible and practical reconfigurations were recommended.

Key Words: — *Distribution System, Reconfiguration, System Reliability.*

I. Introduction

Many power industries consider the modification of the existing system to comply with RA 9136, better known as the Electric Power Industry Reform Act (EPIRA) of 2001. This law mandates the deregulation of the electric power industry that there must be a competitive environment, improvement of the systems, minimizing line losses and voltage profile enhancement.

As the electric utility industries grow in size and complication, adjustment to existing electric power networks have become increasingly expensive. Engineers are not only involved in the production and equipment but also on services with a sound technical basis (including safety and reliability), and ensuring the lowest possible cost.

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1.1 Statement of The Problem

The primary distribution line of Pampanga Electric Cooperative II (PELCO II), which is the end user of Angeles Power Incorporated (API), links with one of the feeder lines of Angeles Electric Corporation (AEC). This arrangement affects the AEC and API in terms of line losses allocation, reliability and financial matters. In this study, Bacolor load represents PELCO II.

As stated by Electricity Consumers' Code (2003), all electricity consumers shall be entitled to have quality, reliable, affordable, safe, regular, and uninterrupted supply of electric power. But in the study conducted by Guarin (2003) there were 29.09% of the correspondents of AEC that complained on frequent electrical power interruptions.

Apparently, as establishment increases due to newly developed subdivisions, the Bacolor load needs to be modified, for it would add more power interruptions and overloading to the L&S feeder line. The API considers reconfiguration of Astron and L&S feeders as an alternative way to improve the power being supplied to Bacolor. All Astron loads would be transferred to L&S feeder line, and then the Astron feeder line would be abandoned. Bacolor load will use the vacant Astron feeder line to be isolated from L&S feeder. An independent feeder line is now provided for the Bacolor load.

1.2 Objectives of The Study

This study was conducted to evaluate the reconfiguration of two distribution feeders' (Astron and L&S feeders. It tends to:

- Identify the length and line configuration of Astron and L&S feeders.
- Determine the performance of the existing configuration and future reconfiguration of two 13.8 kV feeders during load conditions.
- Determine the flow of active and reactive power in the system and the node or bus voltages.
- Determine the line losses, feeder losses and critical increment loading at load bus.

1.3 Significance of The Study

The significance of this study is enumerated based on the following reasons:

- This study guides the company in determining the consequences of reconfiguration of distribution feeders using balanced load flow analysis.
- The study assists the planning engineer in enhancing the operation ability of distribution system and verifying line loss allocation of API and AEC.
- It recommends practical modification in attaining the main objectives of reconfiguration.

Planning (design) and operating criteria may be either deterministic or value- based (probabilistic).

Deterministic criteria are most common and based on experience and judgment; certain credible restrictions are selected for the assessment. Some of these restrictions are as follows:

From Philippine Grid Code, chapter 7.2.1.

- The voltages at all connection points are within the limits of 0.95 and 1.05 of the nominal value.
- The loading levels of all transmission lines and substation equipment are below 90% of the continuous ratings.

From NEA Bulletin (1992), recommended percent loss for primary lines for distribution utility is 3%.

Value based criteria was used in due time to optimize design and operation and requires statistics on frequency of faults, fault type, fault location; frequency of line outages with or without successful reclosing; and frequency generation outages.

As stated by Glover and Sarma (2002) a heavily loaded line with bus voltage (VR/Vs) $\geq$ 0.95 is usually considered safe or good operating practice. Over voltage is an increase of voltage greater than 1.05 and under voltage is decrease in voltage less than 0.95.

II. Methodology

2.1 Identification of line configuration

The conduct of this study follows a procedure to identify and evaluate the reconfiguration of Astron and L&S feeder with the consideration of existing configuration.

The author reviewed the system to disseminate arrangement of the feeder lines. And search for possible way to transfer the loads and use the most practical and economical solution.

The substance of identification of lines and poles configuration is for the computation of the geometric mean distance of conductors.

The monthly maximum and minimum demand of feeders was evaluated based on hourly readings of Astron and L&S feeders. The concern of API is on MW power and power factor. Thus, the MVAR power was computed using power triangle where in reactive power, $Q=P\tan\theta$. The computation of reactive power values was made using GNU Octave 2.1.42, open-source software, downloadable from www.gnu/octave.com/.

2.2 System modeling in per unit

A single line diagram was used for line and source model and applies to all cases covered by the study as shown in Figure 1. For the simplicity of the study, the author considers per- unit value.

The computation of per unit resistance and reactance were encoded to notepad and run to GNU Octave 2.1.42.

2.2.1. Line modelling

Only positive sequence internal reactance was considered in the computation due to balance loading. Formulas and constant variables were introduced in the octave program.

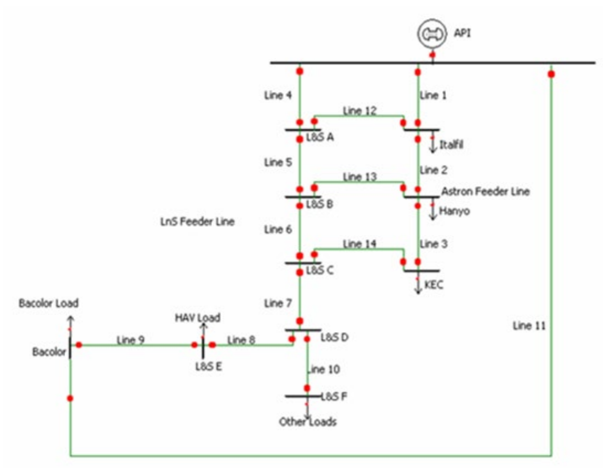

Fig.1. Single Line Diagram of System Modeling

2.2.2. Source modelling

The system operates under normal balanced three-phase steady state; generation (slack bus) supplies the demand plus losses.

To compute for the per- unit impedance of the source, MVA fault and three-phase fault current were also introduced in the Octave program.

2.3 Power flow computation

The power flow problem involves solving a system of non-linear equations and requires the use of an iterative algorithm to develop the correct solution.

PowerWorld Simulator is designed to simulate balanced system and to provide access to the full Newton- Raphson method. It was originally developed at the University of Illinois at Urbana. Its version 11.0(downloadable from http//: www.powerworld.com).

2.4. Input and simulation software

Line losses, voltage profile, line flows were determined using balanced load flow since the loads involved in this study are mostly industrial plants which are utilizing three phase electrical devices.

Single line diagram was created in the Power world simulator platform. The computed resistance and reactance of the line in per unit ohm are used as line parameter and encoded in transmission line option model box. Nominal voltages (13.8 KV) were integrated for the bus voltages. The demand loads were considered as constant power and supplement to load option model box in MW and Mvar. For the demands, non-coincidence peak and off- peak demands were used.

Slack bus generator was supplied to represent API as a source of the feeders. The computed impedance of the source was entered thru fault parameter model box in the generator information menu although this value will not be used in the load flow calculation; however, it can be used for successive fault analysis.

In this study, four cases were presented and analysed.

Four cases are as follow:

Case 1: Base case at peak demand.

Case 2: Base case at off- peak demand.

Case 3: Proposed reconfiguration of Astron and L&S feeder at peak demand.

Case 4: Proposed reconfiguration of Astron and L&S feeder at off- peak demand.

Base case is the existing configuration. Line 12, 13, and 14 are initially open lines and proposed new feeder lines that are needed for the reconfiguration.

The proposed reconfiguration is to transfer all loads of Astron feeder to L&S feeder. Thus, Bacolor load will be isolated to L&S feeder line and used the abandoned Astron feeder line. Line 1, 2, 3, and 9 are detached to the system.

See Figure 2 for the single line diagram for the existing configuration and Figure 3 for proposed reconfiguration.

2.5. Analysis

At peak demand, Case 1 was used to compare with Case 3, while comparison of Case 2 and Case 4 was done under off-peak condition.

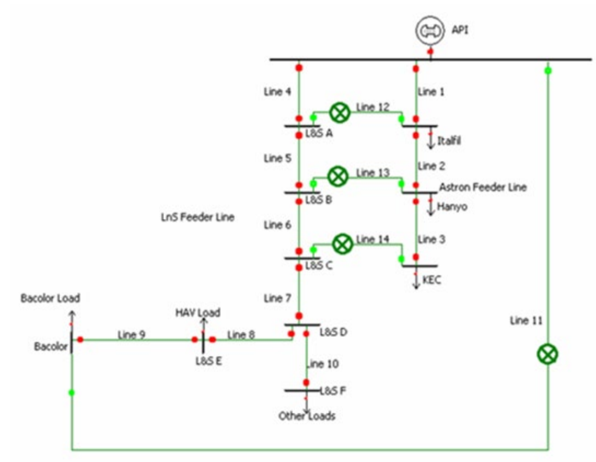

Fig.2. Single Line Diagram of Existing Configuration

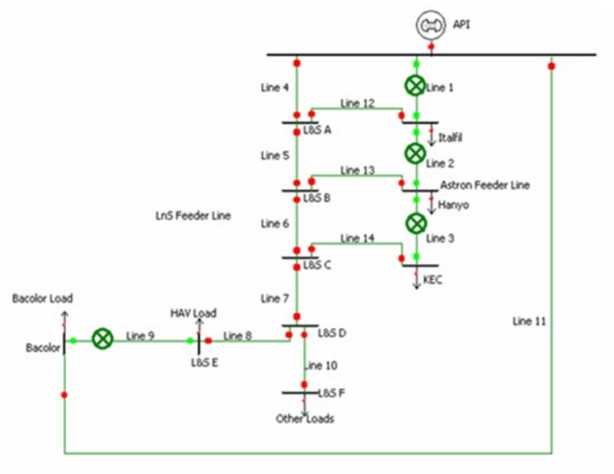

Fig.3. Single Line Diagram of Proposed Reconfiguration

In this study, a deterministic criterion was used. Credible restrictions are selected to test reliability.

Some of the criteria are as follows:

- Voltage magnitudes are within their allowable range of variation.
- Line loadings must not exceed to 90% of its capacity.
- Percentage line losses for primary line of distribution system must be less than 3%.

Based on the test results, the conclusion and recommendation were created.

III. Results & Discussion

The impact on reconfiguration of two 13.8 kV distribution feeder of API - AEC substation was determined using balanced load flow which involved industrial plants that operates three phase electrical devices. The power flow performed in Powerworld Simulation that applies the iterative technique Newton- Raphson method, evaluates the impact of reconfiguration.

For safety purposes lines must not be loaded greater than 90% of its rated MVA capacity. The highest loading is 3.976 MVA (48.92% MVA) at Line 4 under Case 3. The lowest loading is 0.01 MVA (0.12%MVA) at Line 13 in Case 4.

After reconfiguration at Case 3, the line load increased by 15.91%, expect for line 8 (bus L&S D to bus L&S E) which decreased its line load by 59.94%. At Case 4, there is a decreased in line loads up to 70.82%.

The node voltages experienced a few deviations that is within utility practice limit (0.95 - 1.05 per unit) and improvement on voltage at Bacolor bus after reconfiguration.

The total real power loss at base case maximum demand is 51 KW increased to 51.87 KW at Case 3. For base case minimum demand, the total real power loss is 1.48 KW decreased to 1.39 KW at Case 4.

The total reactive power loss at base case peak demand is 62.13 Kvar and increased to 63.17 Kvar at Case 3 while at base case off- peak demand is 1.80 Kvar decreased to 1.69 Kvar.

The losses dissipated by Bacolor load decreased by 90.87% at peak demand and by 84.91% at off- peak demand after reconfiguration, these losses will be allocated to API. The losses imparted by Astron load after reconfiguration were increased 12 times at peak demand and 31 times at off- peak condition. While, HAV and other loads of L&S feeder had losses of 48.09 KW during peak demand and 1.33 KW during off- peak demand. The losses of Astron, HAV and other loads will be allocated to AEC.

The Astron feeder line losses increased at Case 3 by 51.54% and Case 4 increased 20 times the base case. While the L&S feeder losses increased at Case 3 by 1.8% and decreased at Case 4 by 7.48%.

The percentage line loss at L&S feeder is substantial and will be critical in the future. This case may occur particularly when the demand load at L&S F bus has reach to 6.6 MVA at base case and 6.14 MVA after reconfiguration.

Line 1 and 4 were mostly affected after the individual load bus was adjusted to maximum loading. When load at bus L&S F attained its maximum loading, Line 4, 5, 6 and 7 were congested, violated the accepted level of percentage distribution line loss and the per- unit voltage was closed to marginal limit.

It clarified that there were no overloaded lines, voltages were within the limit of good utility practice and percentage line losses were within acceptable level.

IV. Conclusion

Based on the results, it was found out that the effect on line flows, line losses, voltage profile and feeder losses of reconfiguration of distribution feeder in API - AEC substation specifically Astron and L&S is very minimal because of short distance covered and the loads were small. But when dealing with bulky demand or larger and wider distances the impact on voltages and losses were significant.

Proposed reconfiguration is acceptable and reliable for Astron and L&S feeder. It improves the voltage at Bacolor bus. The loss allocation for Bacolor load that is carried by API was decrease. It eliminates inter - utility transaction of API and AEC. In this manner, API will gain the advantage for it will no longer pay wheeling charges to AEC.

Recommendations:

Another possible solution that this study recommends is directly transferring the Bacolor load to Astron feeder line that will lead to voltage profile enhancement, balance loads between the two feeders and the reduction of line losses of the whole system.

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