Increased Resilience Using Close Loop Renewable Microgrids in the Surabaya Distribution System as a Self-Healing Application

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Abstract: Distribution system reconfiguration has two main objectives, namely as optimization of network operations and as system recovery in case of disturbances. It is necessary to consider the reconfiguration process and the process of using Distributed Generation (DG) or microgrid as an additional supply to reduce the possibility of failure, loss of power, or a voltage drop. Therefore the first step in research This results in the candidate bus 14 and bus 52 on the Mulyosari feeder which must be reconfigured by cutting off the flow at L13 and L50 because the losses on both buses are the worst with a value of 0.01370MW and 0.00900MW using the calculation algorithm of Binary Particle Swarm Optimization (BPSO) to predict the location of possible failures and the placement DG, and selected on bus 29 and bus 45 which were injected DG with a PV capacity of 15 kW each, after the self-healing was applied to the system, power flow analysis was carried out, and get good results is very satisfactory with the total losses in the system decreased from 0.363MW to 0.116MW from this study we can conclude that self-healing can only be done if the distribution system is a complex radial.

1. Introduction

we all know, most of Indonesia's networks, especially Surabaya City, are established and operated through a radiation distribution system. Because it has many advantages in terms of economy and practicality, but if the system is disturbed and damaged, it has a weakness. Over time, the power distribution system will form a loop or mesh system, but it runs radially, so some analysis or research on reconstruction methods and power settings is required. When maintenance is necessary execute.

Reconfiguration of a distribution system is defined as the process of changing the topological structure of a network by opening and closing switches and tie switches in cross section. A change in topology is to isolate faults and provide power from different directions while maintaining the radial network configuration. Failures must be isolated to repair failed components and allow operation of failure-free parts. This involves quickly determining the optimal transition sequence for a number of switches.

The distribution system reconfiguration had two main objectives, namely as optimization of grid operations and as system recovery in the event of a disturbance. This research focuses on the last aspect, which can be called self-healing ability when a CB trips after a disturbance in the distribution system, sometimes the CB reclosing process fails so it is necessary to consider the reconfiguration process as well as the process of using Distributed Generation (DG) or microgrid as an additional supply to a distribution system or network that does require additional supply to reduce the possibility of failure, power loss, or drop. Quite detrimental voltage.
Based on these problems, a renewable energy management system is needed that can help in the current supply of electricity. A renewable energy management system that can reach all corners of the country. That is the decentralized system of electricity, this system uses small-scale power plants that are decentralized (scattered) throughout the electricity prone area and require a large electricity supply. The decentralized system, currently referred to as a microgrid system that is very vigorously developed because it utilizes local alternative energy sources without forgetting conventional energy sources. But a more advanced thinking about the concept of electricity distribution has now begun to develop also in various countries, the concept is often called smart grid[2].

Smart Grid is a concept of managing electric energy sources that forms a fully integrated communication network in monitoring and controlling supply availability in accordance with customer needs and detecting and responding in case of overload or disruption and fluctuations in electricity supply[3],[12-14]. The smart grid system enables two-way communication between electricity producers and their consumers, by applying technologies that combine information, communication and electrical power technologies. The application of this technology can maximize the management of electricity sources, electricity supply and efficiency of the use of electricity. Smart grid system can also provide a high level of reliability as a solution to anticipate and detect and respond to disruptions that occur in the system quickly (real-time), the concept of a more stable system, integration of renewable energy sources on the consumer side or in the main generation source area, so that the choice of generation is more diverse that causes the system to become more reliable because of the diversification of electricity sources.

In this study will discuss indicators of self-healing components, including reliability, how to define looping system for self-healing, and benefits of self-healing in the distribution system presented in the city of Surabaya. And in this study researchers have the aim to analyze predictions of self-healing application that is with the addition of some Distributed Generation (DG) especially PV or we know as EBT, so it is necessary to use some calculation algorithms using Binary Particle Swarm Optimization (BPSO) to predict determining the location of possibility failures with the initial sign is a low voltage and power drop on a particular feeder aimed at knowing what things or special indicators need to be considered in the application of self-healing in the distribution system in the city surabaya.

2. Self-Healing Concept
The Self-Healing concept in this study is the process of selecting the bus that has the largest PLine-Losses and how the loop formation process will be processed using the BPSO algorithm as the main process of reconfiguring the distribution system, so that the switch settings must be closed or open and on which bus DG should be added.

2.1. Optimal topology
The optimal topology of a distribution system is one where operating conditions are satisfied with the lowest possible value of system losses. The operating conditions correspond to the voltage regulation, loading, and power factors. To determine the optimal topology, all the poles in overhead feeders and in particular the double dead end poles, or switching boxes in underground feeders, are potential open points. This allows to determine the best boundaries among feeders to reduce the overall losses. Once the optimal topology is achieved, switches, breakers, or even re-closers can be installed in some of the feeders to allow for system reconfiguration[5].

One of the major difficulties in implementing optimal topology methods in distribution systems is to determine the optimal topology which some methods refer to as “optimal separation points.” The packages can have different optimization criteria, such as minimum losses, elimination of overloads, and voltage control. The most common criterion is minimum losses.

2.2 New Grid Configurations
The primary key of the Self-Healing approach concept relies on a distributed control structure by keeping system reconfiguration to a minimum and as local as possible, thereby significantly reducing search space. Although this approach may not lead to a global optimal solution, it greatly increases the computational feasibility.
When an error or disturbance occurs on the bus in the radial distribution network. Therefore, an initial analysis is needed on the system using load-flow so that the amount of line losses will be obtained which will be used as an initial reference for reconfiguration in this system which allows the initial conditions of closed switches to be open and vice versa[6], [11].

After getting the initial conditions of the system, then a power flow analysis will be carried out to obtain the optimal value of the new system configuration to determine the placement of DG and the combination of loops and tie-switches that will be used in the self-healing process in this study.

2.3 Self-healing Evaluation
The self-healing objective is to find a new configuration within its own substation federation. This is done by using possible open tie switches that connect two feeders of the same substation, and then re-check the new configuration with load flow analysis to find out the objective function on section III.A below.

3. Methodology
The previous section introduces the basic concepts of the proposed self-healing approach. The following sections focus on the different steps that are performed and provide an in depth view of the mathematical and algorithmic desc.

3.1 Objective Function
In the self-healing strategy, with the power supply load maximum and the minimum network loss as the goal, comprehensive considering other constraint conditions were optimized.

Maximum power load:

\[ F_1 = \max \sum_{i \in A} S \]  

Where \( i \in A \), \( A \) is the system power supply nodes gather after reconstruction. \( S \) is apparent power load of node \( i \) after reconstruction.

Minimum network loss:

\[ F_2 = \min \sum_{i=1}^{N} k_{Ri} R_i \left( \frac{P_i^2 + Q_i^2}{U_i^2} \right) \]  

Where \( N \) is system all the branch. \( P_i, Q_i \) active power, reactive power and resistance of the branch \( i \). \( U_i \) is terminal voltage of branch \( i \). \( k_{Ri} \) is state of branch after reconstruction. \( I \) means close. 0 means open[10].

3.2 Binary Particle Swarm Optimization (BPSO)
Binary Particle Swarm Optimization (BPSO) is the development of Particle Swarm Optimization (PSO) which is based on the behavior of a swarm of insects, such as ants, termites, bees or birds[2]. Social behavior consists of individual actions and influences from other individuals in a group.

The BPSO algorithm is designed to solve a discrete combination optimization problem, where the particle takes on a binary vector value of length \( n \) and the velocity is defined as the probability of \( n \) bits reaching a value of 1. by limiting the function and by using the sigmoid function, Each particle conveys information or its fine position to the other particles and adjusts the position and speed of each based on the information received about the fine position

3.3 Creating of new Grid Configurations
This section describes in detail according to which rules new grid configurations are generated.

1) Modified Grid Graph: To generate new candidate grid configurations the topology of the grid area under investigation is transferred to what is called here a “Modified Grid Graph” choose the line that has the lowest Pline-losses value and find the alternate bus or line in the system to
get a cycle of the graph and make sure that line can be supply with another source like a DG or grid[7].

To calculate losses using the following formula:

$$\text{Losses} = \frac{\text{Line Losses}}{\text{Feeder/Line Power}} \times 100$$

With:

- \( P_{LS} \) = Line Losses (kW)
- \( P_r \) = Feeder/Line Power (kW)

2) Construction of considered cycle: The main idea of this stage is to create a new cycle/loop that can evolve is that not all loops considered at once but the process begins by considering only the direct cycle around the line that had the lowest PLS value or got highest drop voltage on system. However, not all electrical systems can adopt this loop or cycle technique, only a fairly complex radial distribution system that can be applied with this method. so that after doing this step we get the initial construction of the system, i.e. the total loop and the selected bus for analysis using BPSO as a self-healing candidate.

3) Grid Reconfiguration Constraint: The bus that will be used for calculating the power flow process is the bus that is in direct contact with the loop, including the load in it[9].

3.4 Evaluation of New Grid Configurations

The reconfiguration is carried out for better operation of the network and specifically to reduce the losses due to the Joule effect. Distribution systems should be operated at minimum cost subject to a number of constraints: all loads are served, overcurrent protective devices are coordinated, voltage drops are within limits, radial configuration is maintained, and lines, transformers, and other equipment operate within current capacity. A system reconfiguration changes the topology, line flows, and short circuit values. Thus, different solutions may be feasible for the same fault. In these circumstances, equipment, voltage profiles, and equipment loading have to be considered.

![Figure 1. Distribution system illustrating loss reduction](image)

The exchange process starts by assuming a radial configuration and therefore with the distribution network operating in a radial configuration. One of the tie switches is closed, and then another switch is opened in the loop created, which restores a radial configuration. The switch pairs are chosen through heuristics and approximate formulas to create the desired change in loss reduction. The branch
exchange process is stopped when no more loss reductions are possible. Figure 1. shows a system with four feeders. Here the reconfiguration brings about savings on significant potential losses.

4. Results and Discussions

- Case 1 (Complex Radial Distribution System)

Application of solar energy on catamaran fishing vessels is very useful ($Eb$) and has potential of cost savings of around 90% fuel consumption, also can reduce greenhouse gas emissions. This work is a portrait of a study of development of energy efficient fishing vessels and reducing air pollution.
Table 1. Load Flow Voltage Drop and Plosses

| No Bus | Vnom | Vmag | Vdrop | Plosses | No Bus | Vnom | Vmag | Vdrop | Plosses |
|--------|------|------|-------|---------|--------|------|------|-------|---------|
|        |      |      |       |         |        |      |      |       |         |
| 1      | 20   | 20   | 0.00  | 0.00000 | 45     | 20   | 19.09| 0.91  | 0.00350 |
| 2      | 20   | 19.65| 0.35  | 0.01780 | 46     | 20   | 19.09| 0.91  | 0.00170 |
| 3      | 20   | 19.64| 0.36  | 0.00430 | 47     | 20   | 19.09| 0.91  | 0.00690 |
| 4      | 20   | 19.64| 0.36  | 0.00260 | 48     | 20   | 19.08| 0.92  | 0.00600 |
| 5      | 20   | 19.62| 0.38  | 0.00600 | 49     | 20   | 19.08| 0.92  | 0.00710 |
| 6      | 20   | 19.60| 0.40  | 0.00690 | 50     | 20   | 19.08| 0.92  | 0.00600 |
| 7      | 20   | 19.60| 0.40  | 0.00690 | 51     | 20   | 19.08| 0.92  | 0.00600 |
| 8      | 20   | 19.60| 0.40  | 0.00430 | 52     | 20   | 19.07| 0.93  | 0.00900 |
| 9      | 20   | 19.60| 0.40  | 0.00350 | 53     | 20   | 19.06| 0.94  | 0.00350 |
| 10     | 20   | 19.56| 0.44  | 0.00600 | 54     | 20   | 19.06| 0.94  | 0.00090 |
| 11     | 20   | 19.56| 0.44  | 0.00690 | 55     | 20   | 19.06| 0.94  | 0.00260 |
| 12     | 20   | 19.56| 0.44  | 0.00690 | 56     | 20   | 19.06| 0.94  | 0.00260 |
| 13     | 20   | 19.55| 0.45  | 0.00430 | 57     | 20   | 19.06| 0.94  | 0.00260 |
| 14     | 20   | 19.36| 0.64  | 0.01370 | 58     | 20   | 19.06| 0.94  | 0.00260 |
| 15     | 20   | 19.33| 0.67  | 0.00690 | 59     | 20   | 19.06| 0.94  | 0.00260 |
| 16     | 20   | 19.32| 0.68  | 0.00600 | 60     | 20   | 19.06| 0.94  | 0.00350 |
| 17     | 20   | 19.30| 0.70  | 0.00520 | 61     | 20   | 19.06| 0.94  | 0.00260 |
| 18     | 20   | 19.30| 0.70  | 0.00520 | 62     | 20   | 19.06| 0.94  | 0.00430 |
| 19     | 20   | 19.27| 0.73  | 0.00600 | 63     | 20   | 19.06| 0.94  | 0.00260 |
| 20     | 20   | 19.25| 0.75  | 0.00690 | 64     | 20   | 19.17| 0.83  | 0.00710 |
| 21     | 20   | 19.22| 0.78  | 0.00540 | 65     | 20   | 19.17| 0.83  | 0.00520 |
| 22     | 20   | 19.20| 0.80  | 0.00600 | 66     | 20   | 19.17| 0.83  | 0.00600 |
| 23     | 20   | 19.18| 0.82  | 0.00690 | 67     | 20   | 19.17| 0.83  | 0.00600 |
| 24     | 20   | 19.18| 0.82  | 0.00600 | 68     | 20   | 19.16| 0.84  | 0.00710 |
| 25     | 20   | 19.18| 0.82  | 0.00260 |        |      |      |       |         |
| 26     | 20   | 19.18| 0.82  | 0.00780 |        |      |      |       |         |
| 27     | 20   | 19.17| 0.83  | 0.00600 |        |      |      |       |         |
| 28     | 20   | 19.17| 0.83  | 0.00350 |        |      |      |       |         |
| 29     | 20   | 19.17| 0.83  | 0.00520 |        |      |      |       |         |
| 30     | 20   | 19.17| 0.83  | 0.00520 |        |      |      |       |         |
| 31     | 20   | 19.17| 0.83  | 0.00520 |        |      |      |       |         |
| 32     | 20   | 19.17| 0.83  | 0.00260 |        |      |      |       |         |
| 33     | 20   | 19.17| 0.83  | 0.00430 |        |      |      |       |         |
| 34     | 20   | 19.17| 0.83  | 0.00540 |        |      |      |       |         |
| 35     | 20   | 19.17| 0.83  | 0.00430 |        |      |      |       |         |
| 36     | 20   | 19.17| 0.83  | 0.00600 |        |      |      |       |         |
| 37     | 20   | 19.14| 0.86  | 0.00900 |        |      |      |       |         |
| 38     | 20   | 19.14| 0.86  | 0.00520 |        |      |      |       |         |
| 39     | 20   | 19.10| 0.90  | 0.00830 |        |      |      |       |         |
| 40     | 20   | 19.10| 0.90  | 0.00830 |        |      |      |       |         |
| 41     | 20   | 19.10| 0.90  | 0.00260 |        |      |      |       |         |
| 42     | 20   | 19.10| 0.90  | 0.00600 |        |      |      |       |         |
| 43     | 20   | 19.10| 0.90  | 0.00170 |        |      |      |       |         |
| 44     | 20   | 19.09| 0.91  | 0.00520 |        |      |      |       |         |
From table 1 it can be seen that when in the electrical system in Mulyosari there are two buses that have a large enough PLS, namely on bus 14 and bus 54 so that the bus becomes a candidate bus for self-healing using the help of the BPSO algorithm, before that let’s determine configuration of the system into a series of loops that we discussed in the previous section.

After reconfiguration network system using BPSO as shown in figure 4, it can be seen that at L13 and L51 are switches that connected to bus 14 and bus 52 is open and a new bus through a tie switch will be connected and create a loop and a new system, using the BPSO method is expected to assist in determining the addition of a renewable energy system in the form of PV so that the self indicator healing will be accomplished i.e. keep system reconfiguration to a minimum and as local as possible.
• Case 2 (Simple Radial Distribution System)

Figure 6. Single Line Diagram of the Ometraco bus system

Table 2. Load Flow Voltage Drop and Plosses

| No Bus | Vnom | Vmag  | Vdrop | Plosses  |
|--------|------|-------|-------|----------|
| 1      | 20   | 100   | 0.00  | 0.0000   |
| 2      | 20   | 99.92 | 0.02  | 0.0002   |
| 3      | 20   | 99.90 | 0.02  | 0.0001   |
| 4      | 20   | 99.90 | 0.02  | 0.0000   |
| 5      | 20   | 99.89 | 0.02  | 0.0001   |
| 6      | 20   | 99.89 | 0.02  | 0.0001   |
| 7      | 20   | 99.89 | 0.02  | 0.0001   |
| 8      | 20   | 99.88 | 0.02  | 0.0001   |
| 9      | 20   | 99.88 | 0.02  | 0.0001   |
| 10     | 20   | 99.87 | 0.03  | 0.0001   |
| 11     | 20   | 99.86 | 0.03  | 0.0001   |
| 12     | 20   | 99.88 | 0.02  | 0.0001   |
| 13     | 20   | 99.88 | 0.02  | 0.0001   |

Different from the previous simulation results on a complex distribution system, the application of a self-healing system on a system that only has 13 buses in the example above cannot be used, because the results of the power flow analysis, the voltage drop and losses on the bus are not significant and tend to be very stable. And good with the lowest voltage drop value is 19.97 and the lowest losses value is 0.0002 kW, then it cannot be done or apply self-healing to the distribution system.

5. Conclusion
From the simulation results that have been carried out in the previous sub-chapter, we can conclude that the Mulyosari feeder distribution system on bus 14 and bus 52 is a bus that must be reconfigured because it has a high probability of experiencing interference if the system is in an unstable condition, it can be known because the value The bus voltage drop is quite high, with a value of 0.64 and 0.93 and a losses value of 0.01370MW and 0.00900MW. By using the Binary Particle Swarm Optimization (BPSO) calculation algorithm to predict the location of possible failures and the placement of DG and selected on bus 29 and bus 45 injected DG with a PV capacity of 15 kW each. So in this study we can
conclude that self-healing can only be done if the distribution system is a complex radial and for simple radial types, this method is not good to do. Self-healing research was carried out on several combinations of distribution system types, especially for smart grid systems in Indonesia.

6. References

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