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Transforming an Existing Distribution Network into Autonomous Micro-Grid Using PSO to Reduce Losses & Improve Voltage Profile

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***Abstract* – A distribution network with renewable and fossil-based resources can be operated as a micro-grid, in autonomous or non-autonomous modes. Autonomous operation of a distribution network requires cautious planning. In this context, a detailed methodology to develop a sustainable autonomous micro-grid is presented. The proposed methodology suggests novel sizing and siting strategies for distributed generators and structural modifications for autonomous micro-grids. The Micro grids are modern, small scale, decentralized electrical energy system. These are solution for energy crisis, along with improving the power supply reliability, quality and efficiency. Any time a micro grid is implemented in an electrical distribution system and it have optimal size and need optimal location .The correct size and location of distributed generation (DG) play a significant role in reduce power losses in distribution systems. It represents techniques to reduce power losses in a distribution feeder by optimizing DG model in terms of size, location and operating point of DG. The Particle Swarm Optimization (PSO) algorithm to solve the optimal network reconfiguration problem for power loss reduction. The PSO is a relatively new and powerful intelligence evolution method for solving optimization problems.**

Keyword – Power Loss Minimization, voltage Profile Improvement, micro grid, Distributed power generation, load flow, siting and sizing, particle swarm optimization.

1 Introduction

Recent development in small generation technologies has drawn an attention, to change in the electric infrastructure for adapting distributed generation (DG). Employment of DG technologies makes it more likely that electricity supply system will depend on DG systems and will be operated in deregulated environment to achieve a variety of benefits. As DG systems generate power locally to fulfil customer demands, appropriate size and placement of DG can drastically reduce power losses in the system [1]. To reducing losses there are many alternatives available at distribution level, reconfiguration, capacitor installation load balancing and introduction of high voltage level. There are two type of switches are used in primary distribution system which is normally closed switch (Sectionalizing switch) and normally open switch (tie switch).Those type of two switches are designed for both protection and configuration management resulting in cost reducing [2]. Depending upon the rating and location of DG units there is also possibility for voltage swell and losses are increase. The scenario to exploit complete potential of distributed generation, proper siting and sizing of DG become important. To develop sizing algorithm that transform an existing distribution network to sustainable autonomous system. This operation the generation and corresponding load of distribution network can separate from feeder network. Most of the benefits of employing DG in existing distribution networks have both economic and technical implications and they are interrelated. It is proposed to classify the benefits into two groups – technical and economic. The major technical benefits are:-

- Reduced line losses
- Voltage profile improvement
- Reduced emissions of pollutants
- Increased overall energy efficiency
- Enhanced system reliability and security
- Improved power quality
- Relieved T&D congestion

The major economic benefits are:-

- Deferred investments for upgrades of facilities
- Reduced O&M costs of some DG technologies
- Enhanced productivity
- Reduced health care costs due to improved environment
- Reduced fuel costs due to increased overall efficiency
- Reduced reserve requirements and the associated costs
- Lower operating costs due to peak shaving
- Increased security for critical loads

In [3], a general approach is presented to quantify the technical benefits of DG. A set of indices is proposed to quantify some of the technical benefits of DG. They are:-

1) Voltage profile improvement index
2) Line loss reduction index
3) Environmental impact reduction index
4) DG benefit index

2. Planning of autonomous micro-grid

In radial distribution system has been transformed into micro-grid an introduction of DG`s for autonomous made of operation. The radial structure and relatively high R/X ratio of branches make any distribution system. Hence to reduces distribution losses has been considered as a main objective the transformation an existing radial distribution system into sustainable autonomous micro-grid require DG to be integrated into network. The proper size of these generates and optimal placement of same in network is necessary for its autonomous operation. Power losses vary with numerous factors depending on system configuration. Such as level lasses through transmission and line distribution. Capacitor insulator etc [4]. In distribution system power losses can be divided by two categories first is real power loss and second is reactive power losses. It causes real power losses, while reactive power loss is produced due to reactive elements.

Particle swarm optimization

It is technique used to explore search space of given to find setting required to maximize particular objective. The particle swarm optimization algorithm is new swarm intelligence technique, inspired by social behaviour of bird flocking. This technique first described by James Kennedy and Russell c. Eberhart in 1995, [5]. It was found that with some modification. Social behavior model can serve as powerful optimize. If binary PSO algorithm is dopted, the quantity of switches to be optimized will be very large. To overcome this problem, proposes an algorithm to simplify this network. The algorithm not only minimizes the dimensionally problem but also avoids generation of many invalid particles. The distribution network is simplified through grouping branches are represented by one dimensional coding. PSO is a population-based evolutionary technique that has many key advantages over other optimization techniques like [6], [7]

- It is a derivative-free algorithm unlike many conventional techniques.
- It has the flexibility to be integrated with other optimization techniques to form a hybrid tool.
- It is less sensitive to the nature of the objective function.
- It has less parameter to adjust unlike many other competing evolutionary techniques.
- It has the ability to escape from local minima.
- It is easy to implement and program with basic mathematical and logic operations.
- It can handle objective functions with stochastic nature.

.3. Micro grid Architecture

The micro sources of special interest for Micro grids are small (<100-kW) units with power electronic interfaces. These sources, (typically micro turbines, PV panels, and fuel cells) are placed at customers sites. They are low cost, low voltage and have high reliable with few emissions. Power electronics provide the control and flexibility required by the Micro grid concept. Correctly designed power electronics and controls insure that the Micro grid can meet its customers as well as the utilities needs [8].

4. Micro Grid Components

A. Distributed Energy Resources (DER)

These systems are small-scale power generation technologies used to provide an alternative to or an enhancement of the traditional electric power system. It including distributed generation (DG) and distributed storage (DS) are sources of energy located near local loads and can provide a variety of benefits including improved reliability if they are properly operated in the electrical distribution system. Micro grids are systems that have at least one distributed energy resource and associated loads and can form intentional islands in the electrical distribution systems. [9].

B. Distributed Generation (DG).

These technologies require a power electronics interface in order to convert the energy into grid-compatible ac power. The power electronics interface contains the necessary circuitry to convert power from one form to another. The power electronics interface can also contain protective functions for both the distributed energy system and the local electric power system that allow paralleling and disconnection from the electric power system. These power electronic interfaces provide a unique capability the DG units and can enhance the operations of a micro grid [9].

C. Distributed storage (DS).

Generally the Micro Grid power systems have storage through the generator inertia. When a new load comes online, it can result in a slight change in system frequency depending on its size [10] the storage technologies are used in micro grid applications where the generation and loads of the micro grid cannot be exactly matched. Distributed storage provides a bridge in meeting the power and energy requirements of the micro grid. Storage capacity is defined in terms of the time that the nominal energy capacity can cover the load at rated power.

5. Types of Micro Grid

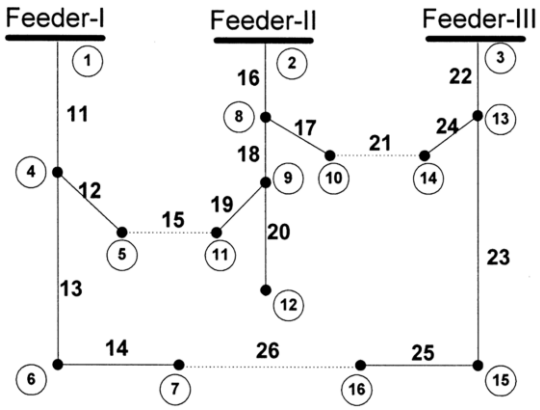
Micro grids are classified in three types.

A. Utility Micro grids.

Utility micro grid can locally meet load growth and manage congestion on distribution feeders and medium-voltage sub transmission networks. At the utility level, small hydro, medium-size wind/photovoltaic (PV) generation farms, biomass, and biogas fuelled power generation plants are some of the alternative renewable energy sources that can be deployed along with low-emission gas-turbine generators to provide adequate levels of supply mix [11].

B. Commercial and Industrial Micro grids.

Commercial and industrial electricity users are normally defined as critical and/or sensitive load classes demanding a high degree of power quality and reliability. A critical load may not tolerate momentary power outages and the level of power quality typically found on most grids. A micro grid can be adopted to serve load demand of a multiple industrial/commercial facility; e.g., a university campus, a shopping centre, or an industrial installation [11].



C. Remote Micro grids.

Remote grids are necessary due to geographical features such as islands. Depending on the geographical characteristics of a remote area and resource availability, diverse types of generation sources such as small-hydro, wind-turbine, solar PV, and low emission gas-turbine sources can be used. A major distinction in remote micro grid design is that the generation sources in a remote micro grid have to be sized to serve the entire load along with an adequate level of reserve capacity for contingency management [11].

6. Problem formulation

The planning of micro-grid to optimally site and size DG is achieved by formulation model as an optimization problem. The optimal sizing and sifting for DG installation lead to highest value of overall benefit one of explanation for introducing DG is improve voltage profile of system and sustain voltage at customer terminal within an acceptable range [12]. In distribution system tie switches and sectionalizing switch are the two types of switches. The tie switches are (10-14) (5-11) and (7-16) in dotted branches conning nodes and switches in other continuous branches are sectionalizing switches. Normally open the tie switches and normally closed the sectionalizing switches. When operating condition have been changed. Feeder reconfiguration is performed by closing /opening of these two types of switches to minimize line resistive line losses. When tie switch may be closed for the purpose of transferring loads to different feeders, and, at the same time, a sectionalizing switch should be opened to maintain the radial structure of the distribution network. When the loads of feeder 2 become heavy under normal operating conditions, the tie switch connecting nodes (5-11) may be closed to transfer the load at bus 11 from feeder 2 to feeder 1 and at the same time the sectionalizing switch connecting nodes (9-10) must be opened to maintain the radial structure of the network.

7. Conclusion

This paper has proposed a comprehensive methodology for transforming an existing radial distribution system fed from a substation feeder to an autonomous micro-grid. A detailed objective function for converting an existing radial distribution network into an autonomous sustainable micro-grid has been formulated. New techniques for determining the number of units required, siting and sizing of the units, and structure of the micro-grid have been developed. An extensive review of the DG technologies and their placement and sizing in a power distribution system using Particle swarm optimization with the view to reduce real power loss and improvement of voltage profile.

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