Design of Power System Distribution Grid Strategy: A Review

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Abstract *— Because it is directly connected to the load centre, the distribution network is one of the most important components of power systems. Integrating renewable and distributed energy sources at the dispersed level is a major challenge for power system engineers these days. Electricity firms and engineers are continuing their research to find new ways to increase power quality and stability in the distribution network. This study examines the notion of distributed network design, kinds, operation, control, management, growth model, and advantages and disadvantages of existing distributed networks, including radial, ring, and meshed distribution networks.*

Keywords *— Architecture, Distribution Network, Radial, Ring, Mesh.*

I. INTRODUCTION

The design and implementation of a dependable and stable distribution network is critical for successful power supply to the load centre. A proper and efficient electrical power distribution system can improve power provision to individual customer premises [1], [2]. Natural disasters, such as earthquakes and cyclones, put the distribution network at risk. The damages sustained can effect the restoration of power network prolongs based on the design, control, and management of that particular network, as each system is designed under natural catastrophe rated units. Substations, primary feeders, transformers, distributor and service mains are common components in a distribution network [3]. The power intensity of a single phase swings between weaker and stronger moments because electricity is created using a sine wave that varies.

Renewable energy sources have recently become popular as a means of meeting energy demand. The network is vulnerable due to a range of developments connected to renewable energy sources and their integration into distribution networks. The degree of vulnerability is determined by network control and architecture, with management playing a critical role in maintaining the network during normal operation.

Energy generating at the distribution level helps both the user and the electricity provider, as generation in the distribution network can reduce transmission losses and power generation costs. [4]–[5]. New technologies in electric utilities are required to deliver superior power quality and dependability to customers. Nonconventional energy generation is becoming more appealing in many countries since it produces energy with less environmental consequences [6] – [8].

The radial network, ring network, and mesh network architectures will be described as the most often used distributed network architectures. A look at the network's structure The applications will cover the benefits and drawbacks of each network structure, as well as the operation, controls, management, growth model, and advantages and disadvantages of existing dispersed networks. The economic feasibility of stand-alone hybrid power system consisting of many renewable as well as conventional energy sources such as PV system, Wind generators, storage battery system and generator system for electrical requirements of the remote locations. It emphasizes the renewable hybrid power system to obtain a reliable autonomous system with the optimization of the components size and the improvement of the capital cost. The survey over the existing energy optimization techniques; further efficiency optimization for future study is mentioned. This paper consists of various modules related to Solar PV technology, MPPT algorithms, DC/DC converters, and grid connected PV inverter topologies, power quality issues with grid connected PV systems have been studied, which form the back bone of the articles. [13] - [16],[19].

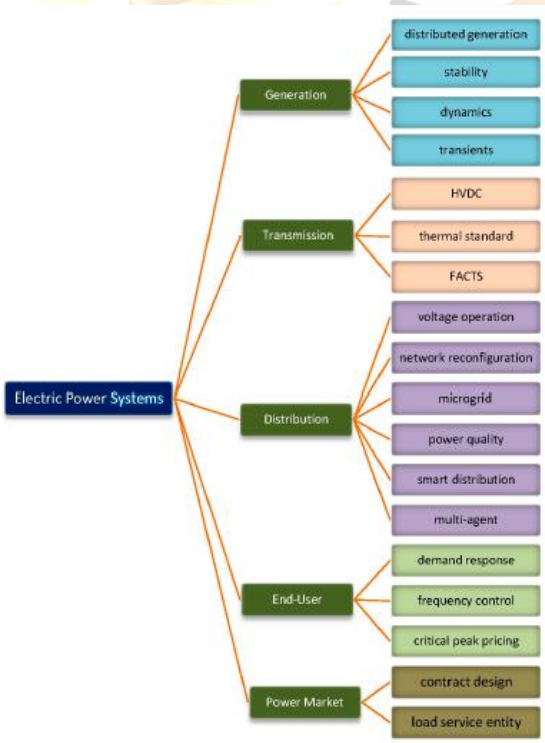

Fig. 1 Electric Power Systems Category

II. EXISTING DISTRIBUTED NETWORK ARCHITECTURE

A. Radial Network Structure

The most often used system for power distribution grids is the radial network [9]-[11]. The radial grid is a topology tree shape in which there are no near loops. Because the radial network has no closed loops, power can be delivered from one bus to another without having to trace down the original bus. However, while turning backwards, it will be necessary to locate the initial bus. This is the simplest and least expensive topology for an electrical grid, however if a line is severed for any reason, all the lines downstream will lose power as well. The structure of a radial network starts at the root node, where the generation is connected. In a radial network, the lateral line follows the root node or main node. This line starts with the main feeder and connects to the connecting loads. The lateral line is followed by the sub-lateral line. The minor lines finally start at the sub-lateral line. Because it is one of the most often utilised ways in power distribution systems, distributed networks with radial network topologies can be examined as an extension of traditional power grid distribution systems [12]-[26].

B. Ring/Loop Network Architecture

The service is looped from a source through a collection of loads and back to the source in a ring distribution network. To put it another way, all of the nodes in the ring network are connected to one another in such a way that they form a closed loop structure that goes around or around a region serving one or more distribution transformers or load centres and returns to the same substation [35]. There is a "null point" on the loop where no power is delivered. This is a dynamic radial system with an open point (null point) that shifts when the load changes. When fed from only one end, a loop must be able to meet all power and voltage drop criteria [32]. The one-line diagram of ring power distribution architecture [36] is shown in Fig. 2. The utility can provide power in any direction of the ring in a ring network. As a result, the defect can be isolated without disrupting service to many of the ring's loads [37]. Due to fault isolation and the capacity to flexibly arrange sources in relation to loads, the ring network structure is very appealing for high distributed network performance. A multi ring structure is a distribution network with multiple connected rings. A large number of power transfer pathways may be offered in a multi-ring system. This gives the system a lot of flexibility in case it needs repair or has a problem.

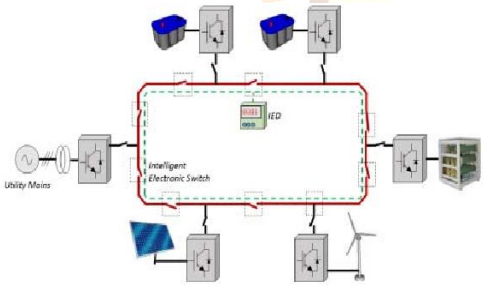

Fig. 2 One-line diagram of ring power distribution architecture

Path multiplicity, on the other hand, makes automatic relaying or protection of a multi-ring system more challenging, because it might be difficult to immediately detect and pinpoint the location of a failure, as well as the appropriate actions to take to minimise customer disruption [38], [39]. When compared to other simpler arrangements, isolating faults becomes more difficult with a multi-ring construction [40]. To isolate an issue, more than one decision could be made, and the best option may change depending on the operating conditions.

C. Mesh Micro-grid architecture

Apart from radial and circular topologies, the electrical grid can also be organised in mesh architecture. Mesh structures are typically employed with high or medium voltage, whereas radial structures are typically used with low voltage [44]. As a result, distribution systems enable the three phases to be offset, and the peak power output moment is evenly distributed over the three phases, resulting in a more constant peak power output.

The radial construction is followed by a mesh network structure, which includes redundant lines in addition to the main lines. These are set up as backups, with the goal of rerouting electricity in the case of a main line breakdown [45]. The mesh dispersed network configuration is shown in Figure 3.

Mesh grid is the most difficult arrangement compared to ring and radial configurations since it includes numerous different connections between nodes. This complicates the operation and security of the distributed network greatly [46]. Mesh grids are less suitable in terms of complexity because they are used more frequently than ring layouts [25]. This could be because mesh dispersed networks use the existing network's configuration rather than creating a new one.

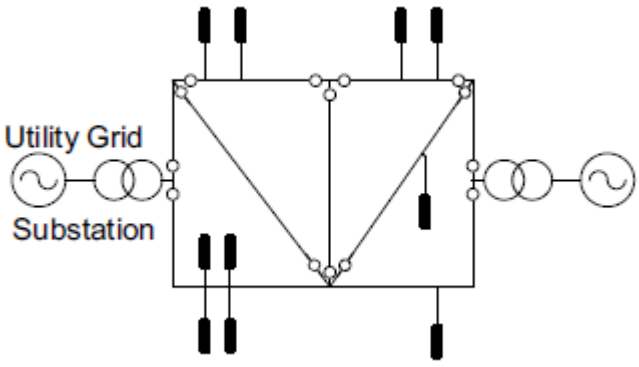

Fig. 3 Mesh distributed network configuration

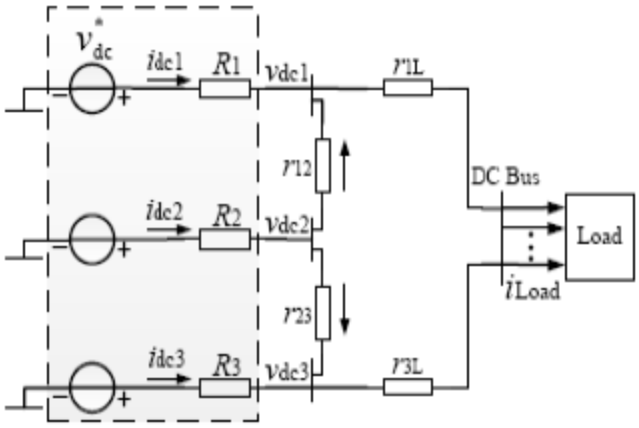

Fig. 4 Simplified model of DC distributed network using Mesh Configuration

III. DISTRIBUTION GENERATION PENETRATION INTO DISTRIBUTION NETWORK

The installation of Distribution Generation (DG) units is at the control of distribution firms. Many research have been carried out to determine how loss varies in distribution networks when DG units are present. Employing DG in existing distribution networks can provide both technical and economic benefits [51], and the accompanying Disadvantages [52] are described below, in addition to the Benefits.

A. Technical Benefits

- Line losses can be reduced
- Improves voltage profile
- Pollutants emission can be reduced
- Energy efficiency can be improved
- System security and reliability can be achieved
- Power quality can be improved
- T&D congestion can be relieved

B. Economic benefits

- Some DG technologies provide less O&M costs
- Productivity can be enhanced
- Health care costs are less because of the improved environment
- Fuel cost is also very less because of the increased overall efficiency
- Reserve requirements and associated costs are also very less
- Because of the peak saving on load curve the operating cost is very less
- Security for critical loads has improved

C. Disadvantages

- Connecting DG in Distribution system causes to flow reserve power flow which results in malfunction of protection circuits
- Stability issues
- Increased fault current
- Asynchronous DG sources which use inverter for interconnection will inject Harmonics into the system.

IV. RELIABILITY ON THE FUTURE TREND

In order to enhance the integration capacity of Energy Generations, future distribution network layout is anticipated to evolve from radial to ring (EGs). The ring operation mode of the distribution network improves the dependability of electric power supply and makes EG voltage control issues easier to manage [53]. The goal of an electrical distribution system is to deliver electrical electricity to clients. In this approach, the system's dependability becomes a big concern. In the contemporary competitive climate of electrical systems, customers need improved reliability. Customers will be inconvenienced, there will be financial losses, and there will be a concern to health and safety if one portion of the electrical system fails [54], [55]. As a result, every attempt to increase reliability is much welcomed.

TABLE I
COMPARISON TABLE FOR RADIAL, RING AND MESH NETWORKS

Network	Sources	Stability	Reliability	Capital Cost	Maintenance	Voltage Level	Protection Required	Renewable Penetration
Radial	Single	Low	Low	Low	Low	Low	Medium	Problematic
Ring	Multiple	High	Medium	High	Low	Low	High	Accepted
Mesh	Multiple	High	High	Low	High	Medium or High	Higher	Moderate

V. CONCLUSION

A review of existing distributed network designs was offered in this research. Radial distributed network architecture, ring/loop distributed network architecture, and mesh distributed network architecture are all examples of this. Each of the aforementioned distributed network architectures is described in terms of its pros and shortcomings, as well as its application. Transmission networks have just a mesh design, whereas distribution networks usually have a radial or loop form. As a result, power flow in distribution networks is often one-directional, with no or little redundancy. Aspects of the network topology also have an impact on interconnectivity. There are a number of active distributed network projects around the world that

are testing and evaluating these advanced operating concepts for electrical distribution systems. As a result, more research into better control and management techniques that are intrinsically potential for future energy systems to achieve reliability, efficiency, and quality power supply should be considered.

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