NETWORK RECONFIGURATION ALGORITHM TO FIND A POSSIBLE SET OF NETWORK CONFIGURATIONS THROUGH SMART GRID TECHNOLOGY

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INTRODUCTION

Electricity power utilities have a key role in enhancing the quality of life of people. This can be illustrated using the correlation between economic growth and the energy demand. As a result, International Energy Agency expected to increase the electricity demand by more than 1000 TWh in 2021[1]. Currently, with the use of modern technology, the electricity sector is experiencing a huge transformation since its creation more than a century ago. The quality of human life in the present day has been vastly improved with the adaptation of automated systems into their day-to-day activities. It is also entered to the electricity utility industries very fast with the advent of telecommunications technologies and software tools, known as smart grids [2]. Smarts grids are equipped with monitoring systems and remote operating systems. Hence, it allows the supply of electrical energy in a controlled and intelligent way [3]. Most significant component of the utility industry is the end user and they are connected to the system through the LV distribution system. However, electrical utility industries are focusing less on introducing smart technology through Low Voltage (LV) distribution systems. Because the LV network is complex due to its network feeder arrangement. However, Smart meters, Smart LV switchgears, Sectionalizes, etc. are currently being introduced to transform the traditional LV distribution system into the LV Smart Distribution System (SDS). As a result, Distribution operators have an opportunity to optimize the system operation and control due to the availability of data and remote control facility in SDS [4].

Utility can maximize the reliability by reconfiguring the LV network arrangement to minimize unserved energy and outages. Hence, the end user can experience a reliable electricity supply. However, utilities are unable to achieve these goals by using manual reconfiguration of the LV network arrangement. Therefore, it is essential to use smart technology in the LV distribution network and a comprehensive algorithm to find out possible LV network feeder arrangements. Then the utility can find the best feeder configuration among them by applying a suitable optimization algorithm according to their requirements.

This paper proposes a novel network reconfiguration algorithm to find a possible set of network configurations through smart grid technology, considering technical constraints and priority from the meshed type selective secondary LV Smart Distribution System. This opens up a new path for network reconfiguration.

CASE STUDY: LV NETWORK ARRANGEMENT

The development of an algorithm is a key step to solving this problem. Algorithm development can be incorporated with the network arrangement through a representation of the LV distribution system or encoding a possible combination. Also it is important to observe the capabilities in the existing network to convert to a smart LV distribution network. Hence, I conducted a field survey to identify LVDN general arrangements in urban, semi urban areas and rural areas in the Western Province South II in Sri Lanka. Figure 1 shows a part of the area consisting 1600 distribution substations LVDN geometrical arrangement in Kaduwela, Korathota area.

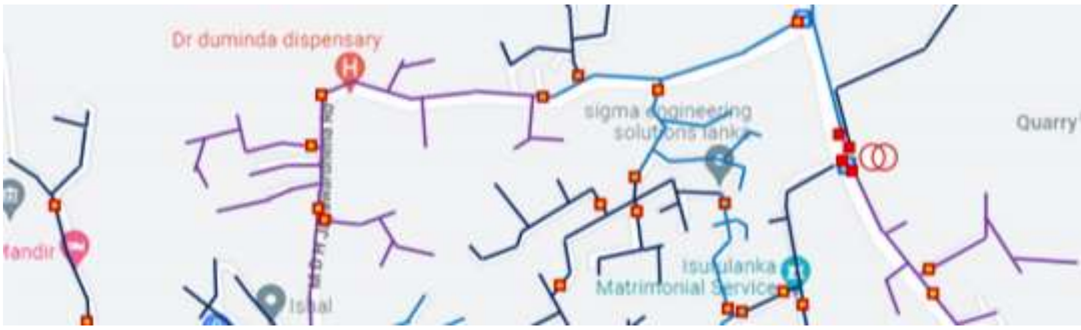


Figure 1 - LVDN geometrical arrangement in Kaduwela, Korathota area.

Generalized LVDN feeder topology model was developed incorporating the field survey and collected data. This representation consists of the encoded possible combination of lines and switches of LVDN in Sri Lanka. This model is presented in Figure 2. The following generalized model is consists of two to four overhead three phase Aluminum bare conductor or Arial bundle conductor feeders, 100 kVA, 250 kVA, 400 kVA, 630 kVA, 800 kVA and 1 MVA, 33/0.4 kV Distribution substations.

Furthermore, the feeder starts with a fuse switch (B) series to the main switch. This main switch is normally a Molded Case Circuit Breaker (A) and it consists of a series of switches called "wire jumper" (C). These wire jumpers are used for connecting or disconnecting the section or branch of the feeder. There is an open jumper point when two feeders meet (D). It is noted that selective secondary feeder topology is widely used in LV distribution networks. In addition to that, during the case study it was observed that smart meters have already been introduced to some areas and are capable of getting remote reading.

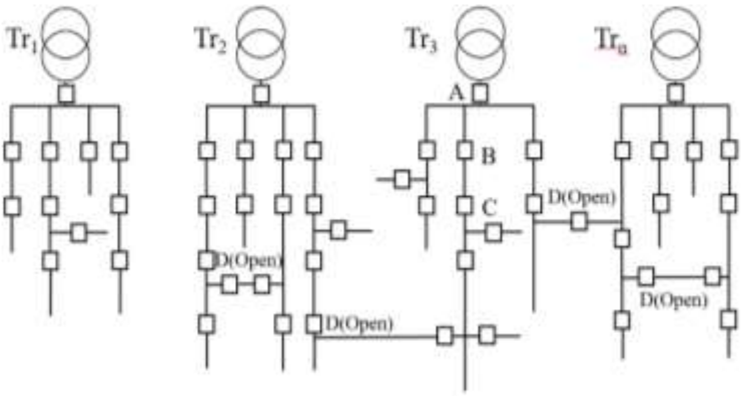


Figure 2 – Generalized LVDN feeder topology model

PROPOSED ARCHITECTURE FOR LV SMART DISTRIBUTION NETWORK

Manually operated traditional complex LVDN can be transferred to Smart LVDN by introducing smart switching devices and smart meters. This is called LV feeder automation. Once suitable feeder automation is introduced, the time taken to detect the status of the network switching devices and real-time field and electrical data collection can be considerably reduced. As a result, processing time for the final network reconfiguration through an appropriate algorithm was also reduced. Time is the key variable of the function of reliability and energy not served (ENS). Therefore, finally both service provider and end user (customer) are benefited with the improved quality of supply.

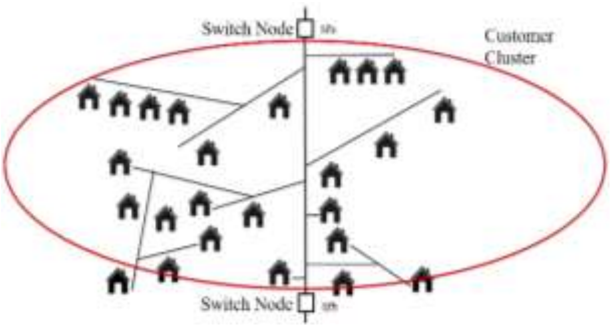
In the manually operated traditional LVDN, there are only three switching devices mentioned as, Molded Case Circuit Breaker (MCCB), Fuse and jumper wire. MCCB and fuses can be replaced with motorized MCCB. Also jumper wire can be replaced with motorized MCCB or Isolators. As implied by the name, Smart, motorized switching devices can be monitored and controlled remotely. Hence, these switches are required to be connected to a Supervisory Control And Data Acquisition (SCADA) server integrated with Remote Terminal Unit (RTU) and Open Platform Communication (OPC) via a wired or wireless communication medium. Not only switching devices, smart meters are also to be connected to SCADA. The OPC and RTU work as a data concentrator. The data is structured using a human machine interface (HMI) in a more user-friendly format for the operator which enables to take necessary decisions. Decision making such as optimizing ENS, maximizing reliability, etc. also can be automated by introducing algorithms. The proposed architecture for LV Smart Distribution Network is shown in figure 3. The proposed system consists of two sections, main control center

and field devices.

Figure 3 – Proposed Smart LVDN

ALGORITHM TO FIND A SET OF POSSIBLE NETWORK CONFIGURATIONS

The developed algorithm is based on two separated data structures, namely, Customer Cluster and Customer Switch Node. The customer cluster is the zone demarcated within the boundary of the feeding switching devices. Customer Switch Nodes are switching devices which can feed Customer Cluster. Figure 4 (a) illustrates Customer Cluster and Customer Switch Node and



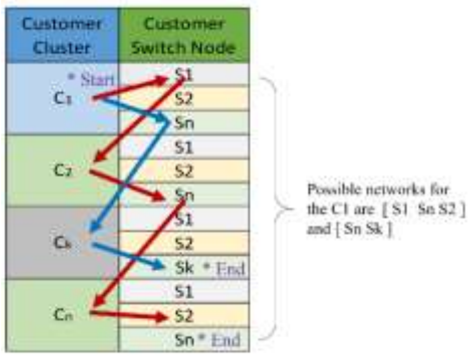


Figure 4(b) illustrates the algorithm concept of the search for all possible network configurations to a selected customer cluster.

Figure 4 (a) – Customer Cluster and Customer Switch Node

Figure 4 (b) – Principle for finding the set of possible network configurations

Detailed data structures of Customer Cluster and Customer Switch Node are shown in table 1.

Table 1 - Detailed data structures of Customer Cluster and Customer Switch Node.

Customer Node Switch(S)		
Code (Name)	String	
Type(Fuse/Isolator)	Fuse = 1	Isolator = 0
Operatable(Yes/No)	TRUE	FALSE
Priortize(Yes/No)	TRUE	FALSE
Present Status (Open/Close)	TRUE	FALSE

Customer Cluster (C)	
Code(Name)	String
Number of Customers	Integer
Prioritize time	Time and date
Prioritize Duration from start time	Integer
Expected Demand	Double
Length of the custormer node	Double
Connected switch	List

Initially this is carried out by starting with a feeding switch node and then proceeding to a next customer cluster adjoining the selected feeding switch node while meeting a fuse or MCCB. Once the switching device (fuse or MCCB) is encountered, the algorithm gives the network path and starts to find all possible network paths by following the same concept. During this process, the algorithm always verifies technical constraints such as which switching devices are available and allowable for the operation. Not only technical constraints, the algorithm also considers priority requirements set by utility and end users (customers). Figure 5 illustrates the developed algorithm.

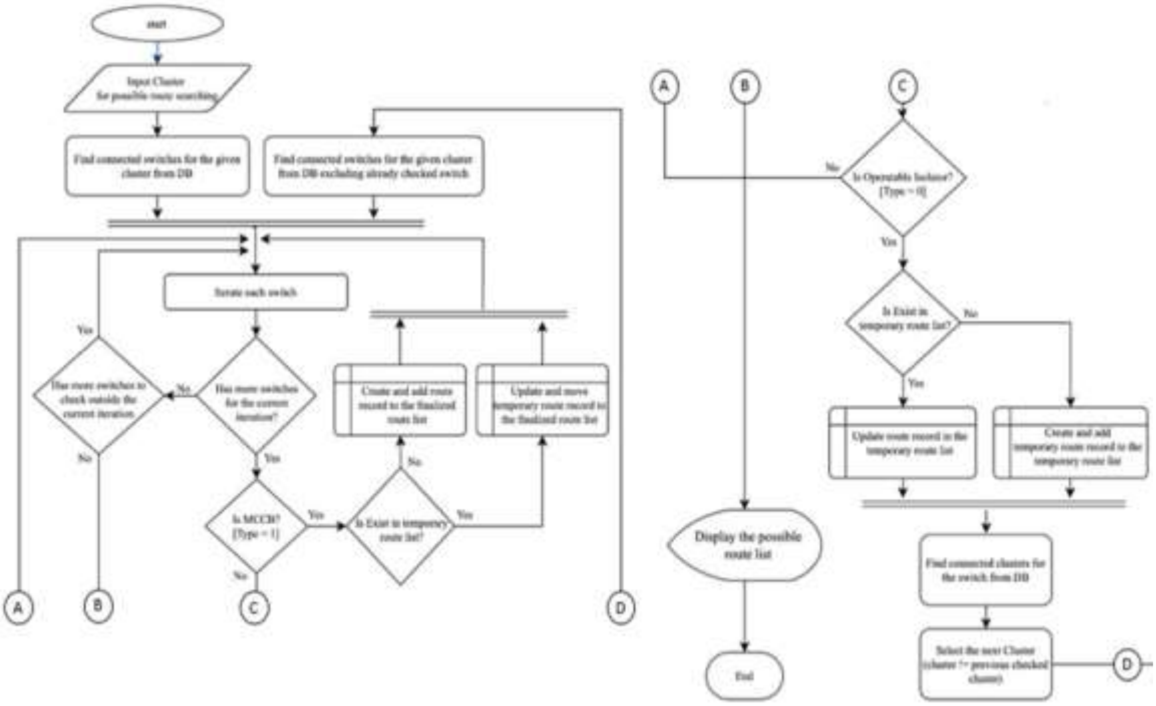


Figure 5 - *Developed algorithm for finding a set of possible network configurations*

TEST RESULT

The developed algorithm has initially been tested for all possible feeding network arrangements considering all possible scenarios such as directly connected to the fuse, without alternative feeding arrangements, feeding arrangement with single source and multiple source, constraint of switches such as non-operational and not allowed condition, etc. Since the existing LVDN has not been fully transferred into a smart LVDN and a model is adequate to verify the above algorithm, a software-oriented database is created for the general representation of LVDN as shown in figure 6.

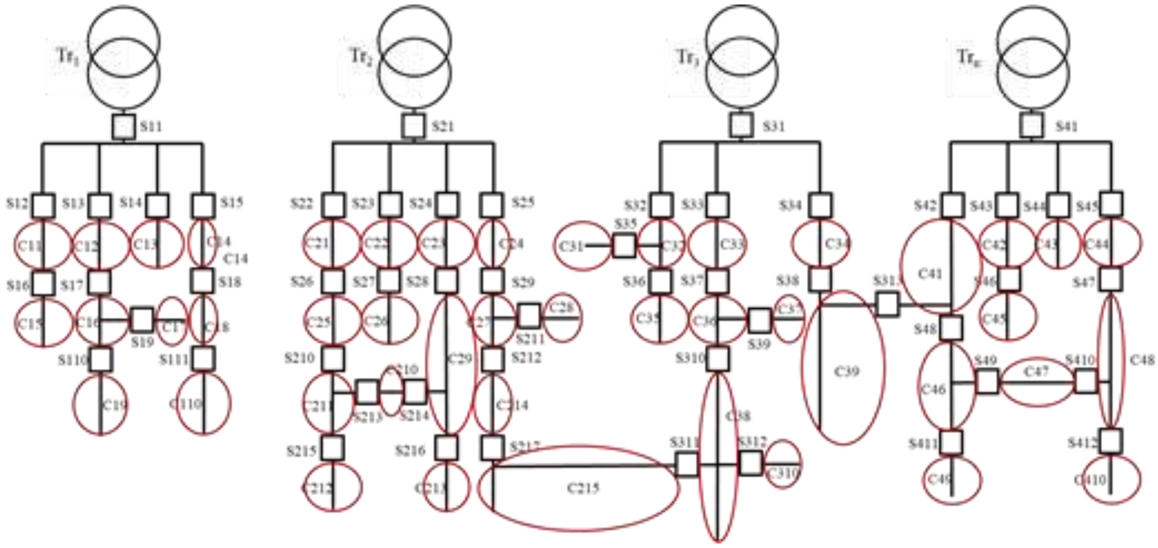


Figure 6 -Database created for the general representation of LVDN.

In order to verify the accuracy of the algorithm the same was tested for the real LVDN system in Kaduwela, Korathota area of Sri Lanka. Figure 7 shows part of the developed algorithm using the MATLAB.

```
%find each neighbouring switch zones
for a=1:numel(switches) %related switch
   for t=1:m % t zone
      for s=1:(n-1) % s switch
         if switches(a,1)==data(t,s+1)
            relatedS(a,d)=data(t,1);
%              SwitchNzone(d,1)=switches(a,1);
            if relatedS(a,d)~=Interruption
               SwitchNzone(g,:)=[switches(a,1) relatedS(a,d)];
               g=g+1;
            end
            d=d+1;
         end
      end
   end
end
[p,q]=size(relatedS);
% for l=1:

disp('Possible switching combinations')
disp(switches)
```

Figure 7 - Developed algorithm using the MATLAB.

Generalized LVDN feeder topology model is validated using this developed algorithm and is further verified using a real scenario in Kaduwela, Korathota area of CEB. Test results for Substation No. 3 are shown in table 2.

Table 2 - Test results for the Substation No. 3.

Customer Cluster	Possible network configures
C38	S311 , S217 , S212 , S29 , S25 , S21
	S310 , S37 , S33 , S31
C310	S312 , S311 , S217 , S212 , S29 , S25 , S21
	S312 , S310 , S37 , S33 , S31
C36	S310 , S311 , S217 , S212 , S29 , S25 , S21
	S37 , S33 , S31
C37	S39 , S310 , S311 , S217 , S212 , S29 , S25 , S21
	S39 , S37 , S33 , S31
C33	S37 , S310 , S311 , S217 , S212 , S29 , S25 , S21
	S33 , S31
C32	S32 , S31
C31	S35 , S32 , S31
C35	S36 , S32 , S31
C34	S34 , S31
	S38 , S313 , S42 , S41
	S38 , S313 , S48 , S49 , S410 , S47 , S45 , S41
C39	S38 , S34 , S31
	S313 , S42 , S41
	S313 , S48 , S49 , S410 , S47 , S45 , S41

CONCLUSION

In order to develop the proposed Smart LVDN, the authors studied the existing traditional LVDN and ability to transform to the smart LVDN by introducing Smart switching devices and suitable SCADA infrastructure. The paper discussed how to minimize the number of operations of the switching devices to single operation when network reconfiguration takes place based on optimization multi-function objectives. An open algorithm is introduced to find a set of possible network configurations for any selected customer cluster. The proposed algorithm is tested using a software-oriented database. Further, authors intend to extend their research to develop an algorithm for a multi parameter LV network topology optimization which is to be used in advanced distribution management systems operated through Smart Grid Technology.

ACKNOWLEDGEMENT

The authors would especially like to acknowledge the support given by Eng. J Meegoda, Additional General Manager (DD1), CEB and Dr. Narendra De Silva, General Manger, Lanka Electricity Company (LECO) in various capacities.

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