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Modeling the distribution grid by Petri Nets for reconfiguration the power system

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Abstracts: The focus of the present paper is on modeling the distribution grid using Petri Net for reconfiguration. Such system can be described as node and connection. So modeling this system is to model the node and connection in order to describe all the actions in the system then collect the data . Each connection in the power network will be transfer to Petri Net according to the designing of the fiche. Then the whole system can be modeled by Process Algebra Petri Net (PPN). It makes the grid more compact and easier to monitor

Introduction

Today, the reconfiguration of power networks, especially distribution networks under breakdown conditions, is determined by various off-line computations. The current applied practices, however, rely greatly on experience of operators and immutability of network topology. Such methods can easily fail when some exploitation constraints cannot be respected. To solve these problems, the necessary to develop an effective and reactive tool is mandatory.

Some approaches have been applied to solve this problem. Classic approaches generate all possible configurations and choose the best for one or more criteria set (operations, losses, margins, costs, etc.) [1]. Memorization approaches calculate and store the best configuration for all trips and for different load cases and then they identify in real time the load case that the more resemble with the current case [2]. Optimum approaches use an optimal method for network by having defined optimization criteria that penalizes overloads [3] and cutting approaches create a set of rules that can cut the isolated areas in number of small areas that are supplied again one after the others. Moreover, most of modeling in power system relates to restoration plan [4, 5, 6] or to analysis the power grid [7-9] for example: the operation of generator, load, transformer and then check the properties of this system when connect the devices

However, these approaches expose some limitations such as computation time restriction, computation complexity, sometimes far from the global optimal point or not very adapted to keep a track on data evolution and so isolated zone after the fault [13].

It is the reason that we propose in this paper one method to model the distribution grid, called operation-part model by using Petri Net tool

This paper is organized as follows: section 1 is introduction, section 2 focus on problematic, section 3 is proposed approach to model the grid and the last is conclusion and perspective.

Problematic

The purpose of distribution networks (DN) is to provide energy to customers using low voltage (LV) or medium voltage (MV). To ensure safety and simplicity for the system exploitation, these networks are operated with a tree configuration. So there always exist some tie switches that are set "normally open" (circuit breaker 2 and 3 in Fig. 1).

After occurrence of a network failure and detection of the faulty part, a small part of the network will be isolated (faulty part) and the supply of some healthy parts will be cancelled. The duty of operators is to find an emergency path which can reenergize the healthy parts while ensuring that there will be no rising problems in other parts of the network. Besides, it is essential to minimize the unsupplied energy during the reconfiguration. These actions can be done by normally using open switches that link feeders

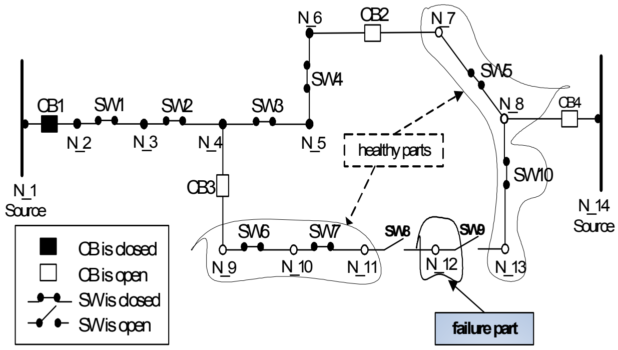

Fig. 1 Initial state of network after a fault

For example, in Fig. 1, CB2 and CB3 are normally open switches (tie switches). The faulty part includes node N_12. This part is isolated by opening and deactivating the SW8 and SW9. There are two healthy parts that are not supplied: part 1 comprises three nodes (N_7, N_8 and N_13) and part 2 comprises three nodes (N_9, N_10 and N_11).

Following an outage, network restoration must be carried out in the fastest and safest manner. For being accepted, the solution must respect the maximum capacity of lines and sources and the acceptable rules for switching operation as well, depending on the used restoration principle. In general, the reconfiguration process can be divided into two sequential stages: the first stage determines what topological modifications must be performed to reenergize all the healthy nodes; the second generates operations list. This operations list identifies all the required operations on the switches and circuit breakers.

The process begin thus by considering the fault area and look for electrical paths to supply again the healthy parts (in Fig. 1, these paths are established by closing CB3, CB2 or CB4). If these paths can be found and do not create overloads, the solution will be accepted. If there are overloads created, we will try to remove by connecting them with lines from others feeders and therefore by changing drastically the network configuration. Such processes are called load transfer. The configuration changes will be made in a proper way to limit the number of modifications. Local modifications will be mainly implemented by using one or several neighbor feeders to reenergize the outage area. Some load transfers are performed to decrease the load of neighboring feeders in a recursive way, starting from the faulty area and ending with the farthest lines in the network.

Once a feasible solution has been found, the initial state (the network status after a fault) and the desired state (the network complying with all constraints) are known. The switching list between these two states must thus be established.

Let us note that the required processing time will be less than ten minutes in France. The computing time to figure out solution is very critical and it helps to reduce the electricity cut-off time

Modeling the grid by Petri Nets

This method inherits and develops from Henry Sebastien and Hieu Nguyen [7-8]. In Hieu approach, he proposed specific operation model to represents the power grid from a discrete point of view. Theses operation models describe not only all the actions proposed by the actuators of the grid (switch, circuit breakers, …) but also all corresponding information such as: conditions and constraints to launch an operation, effects, and so on.. This kind of modeling is very interesting from an expert point of view to acquire the knowledge on the process, but presents some disadvantages such as: not to prove the correctness of the model (reversibility, boundedness and the deadlock-freedom properties), using the model to formally find a control sequence, and so on. It is the reason why we propose here to translate first the operation model proposed by H. Nguyen in a formal model as Petri Nets models.

The first step of modelling the grid is to model the connection (switch, circuit breaker) to describe its operation in the system. Before starting one operation, constrains and condition must be ensured.

The distribution network model is made up of node and connection. Connection considers to the on/off devices in the grid: circuit breaker and switch. Node is defined as the intersection of two or several connections.

In the power system, to connect the power to the node, the conditions and the constraints need to be ensured for safety.

Constrains are defined as the conditions to avoid the confliction in the system (physical relations) Conditions are defined as the conditions in order to obtain the end of the effect. Conditions and constrains can be called resource as well

The effects are appeared when the condition and constrains was satisfied before.

One process to connect the power, all resources (Res.) must be guaranteed before generated the effect. It is sequential process, this is one reason to use Petri Net to model the grid. In order to transform to PN, the behaviours of the system will be transfer to the components of PN: transition, place, token.

The place will be role as the resource and the token represents the availability of the resource due to the reaction in the power has a fast speed so the input of this system must be controlled. With the token in the place, the resource can be monitor easier. Effect is the result when the resources are satisfied, therefore the place will be also substitute for the effect. The transition describes one operation from the beginning to the end.

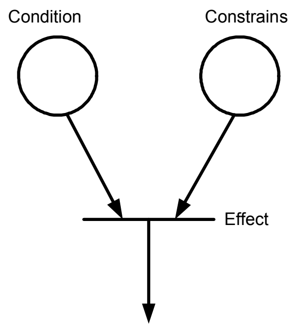

Fig. 2 Illustration of Petri Net model in grid

In order to get the Petri Net model, one operation must be known three information: the constrains, conditions and effects. To combine all these information, one fiche will be created to collect it as fig. 3

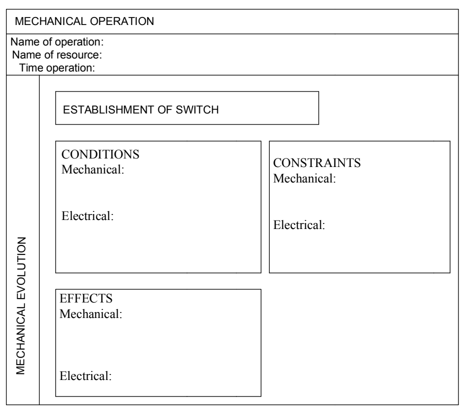

Fig. 3 Description of one fiche

From the specifications to open or close the switch or circuit breaker, we can generate the fiche easily for all logic devices. For example, the fiche and the Petri net connection model is complied as followings for close the switch and close circuit breaker:

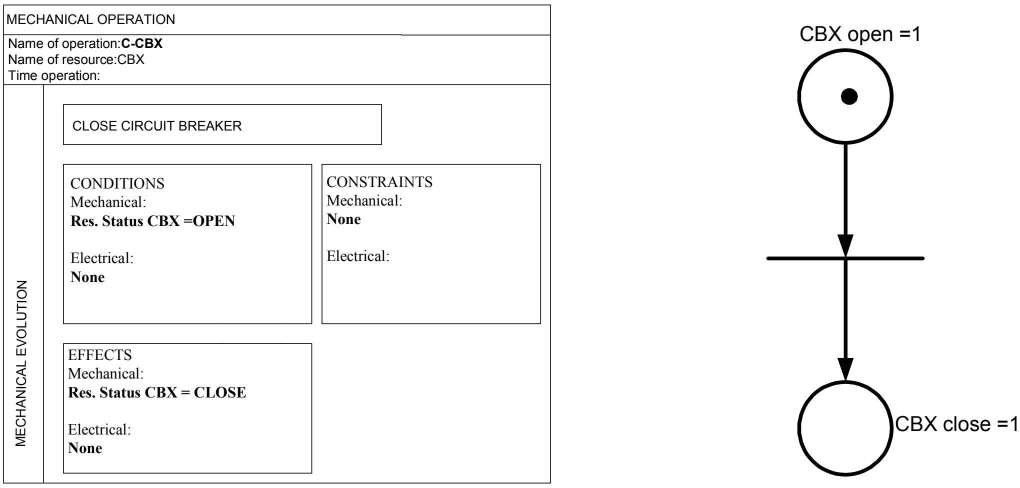

Fig. 4a Connection modelization with the circuit breaker

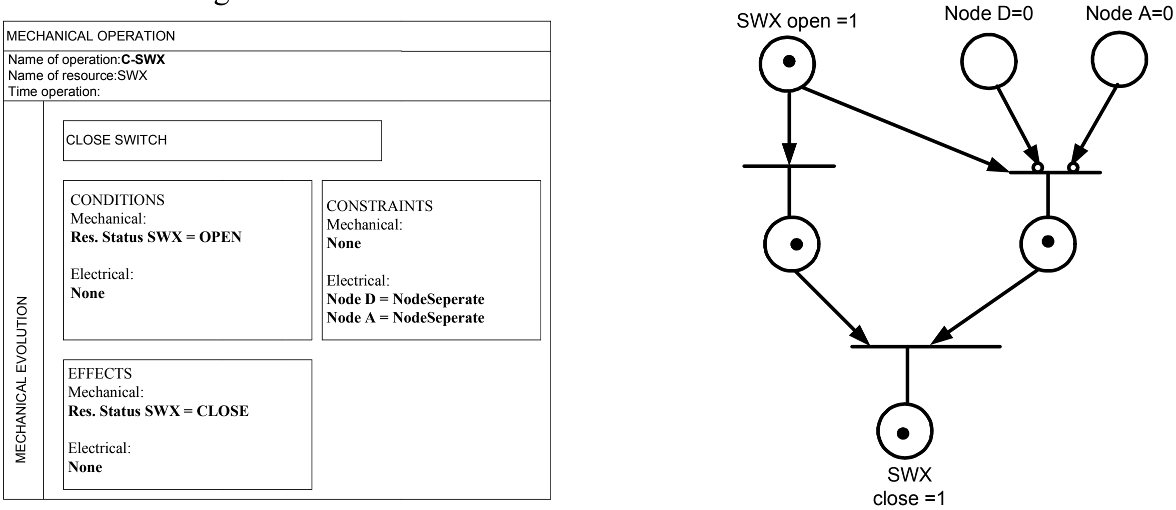

Fig. 4b Connection modelization with the switch

(Node D and node A symbol for node depart and node arrival, between one connection, node separate means that the its voltage is zero)

When the connections are modeled, all elements in the grid must be connected to each other. In this case, one kind of Petri Net- Process Algebra Petri Net [12] is used because it has enough operators to model the system as listed in Table 1

Table 1 Operator in Process Algebra Petri Net (PPN)

Operator	**Description**
P_1 -> P_2	Process P_1 followed by process P_2
$P_1 + P_2$	Alternative choice between P_1 and P_2
P_1 & P_2	The start and end of P_1 and P_2 is synchronized
U{$P_{1,\ldots,}P_n$}	Parallel execution of $P_1, P_2, \ldots, P_n$
Restriction	State(s)
$[P]$	Initial state in process P
$[P]$	All states except the initial state
$P_1[P_2]$	P_1 executed when P_2 is in its initial state
$P_1[P_2 \wedge \overline{P_3}]$	P_1 executed when P_2 is in its initial state while P_3 is not

Apply in Fig 1, the system modeled by PPN can be rewritten:

$$\{P1 \rightarrow (P2\&P3)\}+P4$$

with P1 = {N1, N2, N3}; P2 = {N4, N9-N14}; P3 = {N4, N6-N8}; P14= N14

Conclusions

The objective of this paper is to model the power system for reconfiguration plan. By using Petri Net for modeling the connection and the node, using PPN for combining all the devices in the network, an operation part model can be created. The designed system is compact and visual. From the fiche, it is easy to check the correctness of the model- this can not be done in Nguyen's model. Moreover, with operation part model, we can update the changes of system then we can find all configuration possibilities to supply the power to isolate area.

For future work, the problem that need to be solve is which possible configuration can be the best choice for the safest exploitation and the path to evolve to the configuration chosen from the current configuration" by using Petri net

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