This is the accepted version of a paper presented at 55th Conference on Simulation and Modelling (SIMS 55), Modelling, Simulation and Optimization, 21-22 October 2014, Aalborg, Denmark.

Citation for the original published paper:

To promote electricity smart grid performances by numerical modeling applications.
Linköping Electronic Conference Proceedings

N.B. When citing this work, cite the original published paper.

Permanent link to this version:
http://urn.kb.se/resolve?urn=urn:nbn:se:mdh:diva-26848
To promote electricity smart grid performances by numerical modeling applications
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Abstract:
Wide world’s utilities are generating, transmitting and distributing of electricity throughout the country and are responsible to its quality.
Distributed automated distribution system has been proposed for planning to reduce losses, optimize capacity and load balancing in electricity networks. The world electricity average loss is about 8% and outage per customer time is about 10 min/ year. The indices are needed to optimize in developing countries.
This paper deals on a modeled distribution system in Sari distribution region and evaluates three mentioned parameters on network quality. Restoration, maneuvers to achieve the minimum loss, reactive power controlling, load balancing etc are investigated.
Modeling performs by MATLAB software, EMTP for transient modeling and Digsilent with real data by Sari Distribution Company. In this paper, a new approach by rearrangement aimed at reducing losses and improving of load balancing in distribution networks was presented.

I. Introduction:
The smart grid is an intelligent and advanced power grid that utilizes electric and information communications technology to provide high quality power services by maximizing energy usage efficiency, indexed by KEPCO. Utilities have to supply world-class electricity to its customers and try to improve the efficiency of its power supply, transmission and distribution facilities to the world-best level.
European, North America and South Asia utilities are more developed rather than to Middle East and African companies. Tavanir in Iran is doing this task as a mother company. In Iran, more than 255000 million Kwh electricity generated in 2013 through the more than 70000 MW installed power stations. Peak load occurred in 5 August with about 46000 MW. Losses in Iran are averagely 15%, Tavanir reported. While South Korea’s installed capacity in 2013 was 81,806 MW and the peak load reached to 75,987 MW. It means Iranian electricity strategy have to be aligned in the field of clean energy with smart grid. Authors focus on Iran’s network as developing countries that need to improve distribution networks indices.

Modern electricity distribution system with DG, micro renewable energy, electric vehicles, storage and frequency stabilizing (battery, flywheel, etc) systems need to accommodate new technologies with challenges. Greater computations to gather with higher uncertainty are main concern in complicated modern developed distribution systems. For example, the latter arises from the increasing granularity of modeling and control devices across transmission and distribution all the way to households.

Advanced modeling and analytical techniques are developed to help better maneuvering-restoration, understand and design widespread distribution grids. This is performed by scenarios according to technology and policy changes, probabilistic modeling loads, using of learning mechanism, smart scanning tools for system properties such as stability and multi-objective stochastic optimization on networks for planning.

Because of that grids must become more adaptive to maneuver; demand, unwanted faults and expansions, a model of network to pre evaluate of conditions help to operator. Mindless maneuver cause significant
damage to the network energy distribution. It needs an effective algorithm for optimizing distribution system operation in a smart grid, from cost and system stability points of view. It should be proposed an algorithm with the least possible cost while giving the highest priority to loads and DG. Then a recovery algorithm can be used to provide decision support to mitigate undesired effects and present a well plan. A simulated condition can help to understand forward actions. It is needed to formulate the power restoration planning and recovery problem as a stochastic optimization problem which takes into consideration the physical properties of the power network and the vehicle routing of repair crews.

The smart grid efforts on getting better use of huge data coming from feeders, loads DG equipped with advanced intelligent electronic devices (IEDs) such as digital protective relays, digital fault recorders, remote terminal units of SCADA, smart meters, equipment monitors, etc. As the amount of the smart grid data increases in the future, it becomes critical that the data integration and conversion to information be performed automatically. A major challenge remains to convert information into actionable knowledge.

An algorithm which is mainly dependent on forecasted data of the power available from different sources as well as the load demand, a full attention has been paid to the forecasting process. Hence, a non-linear regression technique has to be applied to build accurate forecasting models for different sources and for the load. These models help in monitoring and predicting the total power generation and demand online. Furthermore, a controller such as fuzzy based should be utilized to make use of the forecasted data of the coming peak period then decide dynamically the amount of power that should be taken out of energy storage.

Different case studies must be investigated to verify the validity of the proposed algorithm and define the system behavior under several conditions.

Development of a wide area measurement (WAMS) system for smart grid applications is necessary. This system is based on synchronized phasor measurement technology with the access of a broadband communication capability. The purpose is to increase the overall system efficiency and reliability for all power stages via significant dependence on WAMS as distributed intelligence agents with improved monitoring, protection, and control capabilities of the power network. WAMS can increase the system reliability as well. The communication layer consists of three PMUs, located at generation and load buses, and one Phasor data concentrator (PDC) collecting the data received from remote PMUs and send it to the control center for analysis and control actions. The power system status can be easily monitored and controlled in real time by using the measured bus values online which improves the overall system reliability and avoids cascaded blackout during fault occurrence. The simulation results must confirm the validity of the WAMS technology for smart grid applications.

Smart grid can handle a grid in island operation, manage generation and load balancing, manage separation and parallel with other grids, improve grid access, increase grid availability, allow production dispatchment, allow demand response and demand side management, promote the development of an energy market, allow
energy network integration (Gas and electricity), allow grid services exchange etc. Those abilities of smart grid help to utilities to deliver stable, continuous and low outage electricity to customers.

II. Modeling and simulation investigation

General objectives of modeling and simulation are to define the project vision, the fundamental concepts and the system architecture. Also to develop the necessary tools to support all project phases through numerical simulations.

The chosen reference network is a typical distribution LV and MV grid, working in radial mode with the possibility of connections. It includes feeders departing from one LV/MV substation.

Adopted Software Platforms are Dig Silent for the steady-state phenomena analysis and EMTP-RV for the transient analysis.

Developed models in the modeling can be Gas turbine and wind generator, Static VAR compensator, Dynamic loads, Lines, protections and substations. Developed DMS and EMS functions are including of Generation curtailment, Load shedding and Voltage and power control strategies with coordinated behavior of generation units.

At the most recent years, MATLAB used for calculation and AutoCAD has been used for drawing a designed network. It took several times to calculating, drawing and editing. A well experienced engineer with a good capability in software was used to do this hard job.

Today, to simulate of super distribution grids (Smart network) occurs several Challenges that should study more and more.

Data and data portability between power system applications, Visualization and analysis of huge systems, Parallel computations, Real-time computations, online analysis, Unification of simulation methods and environments are the main concerns.

Multi-domain simulations are a majority in modeling and have to be paid attention.

EMTP is used to simulation and analysis of electromagnetic transients, detailed simulation and analysis of large scale electrical systems. Network analysis including of network separation, power quality, geomagnetic storm, interaction between compensation and control components, wind generation, synchronous machines: SSR, auto-excitation, control. Power electronics, short-circuit conditions, network interaction, distribution line systems insulation coordination, switching, design, wideband line and cable models. Switchgear side molding like TRV, shunt compensation, current chopping, delayed-current zero conditions can be performed as well.

Modern grids require advanced study and analysis methods: for power system design, operation and post-mortem analysis.

Numerical models and solution methods now play a dominant role and contribute to all research and development levels. The needs for grid simulations increase significantly faster than the capability of researchers to deliver models and faster simulations methods. Simulation and modeling are essential for the evolution and operation of modern power systems.

> Can we build an electronic copy of the operated system?
> Can we merge real-time and off-line simulation tools?
> Can we replicate analog simulator style with numerical simulators?
> What is the highest computational speed?
> How far: wideband and size
Can we unify simulation environments to work with unique data sets and various analysis methods?
Can we create portable models and data?
Use Concurrent and multi-domain simulation methods

**New trends: Cloud computing**

> Applications for power systems
  > Generation scheduling, unit commitment
  > Load-flow
  > Transient stability and electromagnetic transients
  > Complex optimization problems
  > Probabilistic methods
  > Acceleration of simulations
  > Sensitivity analysis
  > Contingency analysis

> Dispatching of computing jobs into a resource pool
> Simulation services with centralized and shared data
> Increased utilization of available computing services
> Higher automation levels
  > Reduced human intervention
  > Private cloud systems
  > Public cloud systems
  > Community cloud: organizations working together

**Parallel computing**

Availability of increasing calculation capabilities through multicore computers make the engineers to faster calculations. Power system simulations involve the solution of linear sparse systems. Traditional methods are generally sequential and use only one CPU. The matrices are very sparse, moderate size, coupled and unsymmetrical and the machine need to a parallel computing to reduce the processing time. For Load flow and steady-state studies the matrices are coupled but the solution is performed once. For time domain it is possible to use the natural delay of the lines to decouple the system. Not always feasible!. It is essential to explore new ways to increase the speed of calculations while maintaining accuracy. Most of researchers are trying to increase the speed of calculations using the possibilities offered by new technologies and by parallel computing. Several simulation tools addressing different aspects, telecom, control, electromechanical and electromagnetic transients, collaborate together to simulate the same power system. Collaborative software environment can be implemented through a co-simulation channel in an indirect interaction (FMI). Use Federated simulation systems run-time infrastructure (RTI) to support interoperability (HLA) is investigated here. Scalable performance via parallel and distributed simulation techniques is discussed.

**Experimental issues:**

Management of balance including independent thermal and electric loads is the first challenges. Operation in intentional islanding and connected to public network must be considered. Study and development of control and interface systems are needed to understand the model description and analyzing. Study of storage and compensation systems with power and quality functions need to model of system in computer. Study and development of protection systems for low short circuit power systems are needed to verify the results by coordination and protection abilities. Development of grid operation and control systems change the model for every step of modeling and should considered.
**Low Voltage Generation Systems:** Micro Grid test facility, Wide spectrum of market available technologies: Photovoltaic Panels, Mini Wind Generators, Small Domestic cogeneration systems and Fuel Cells. Generator size in microgrid system is 10 – 100 kW.

**Electrical and Thermal Load Emulators**
The research activity has to afford themes related to load estimation, modelling techniques and load control policies. As it will be necessary to reply different load trends, according to network power level, an emulation load system will be employed. Through a proper controlled inverter system it will be possible to reproduce active and reactive load power profiles for an amount of about 2MW. The availability of thermal emulation system is essential to dissipate the thermal power produced by co/tri-generative systems, in an independent way of real available thermal users. This system will allow the modulation of the cold/warm load request in order to control generators in different ways (thermal or electrical load follow modes). Thermal load profiles will be reproduced to simulate the real behaviour of this type of systems when they are connected to a real heating/conditioning network.

In order to test a variable topology network some devices could vary total impedance of MV electrical lines or of the upstream network. Through the network emulator the feeding condition of the experimental network could be varied respect to the upstream primary station. The dispatching panel, together with the protection and lines emulation system, will set up a MV feeder, emulating over-head and underground lines for an amount of about 30 km.

Input for modeling are including of: Consumption and generation programs, Real-time Power Request Adjustment and Measurements from nodes are needed. Outputs can be as: Operation Set Point for MV generators and loads and Operation Set Point for LV micro-grid controller. Optimization can be studied around: Power flows on the MV and LV network, Exploitation of distributed energy resources and Power Quality at each network node.

To have a good smart grid is needed to the communication system will ensure: Efficiency by ability to exchange data in real-time mode, Reliability by possibility of retaining data exchange in situations of difficulty of communication (distance, meteorological agents, presence of foreign sources and noises) and to restore the link once interrupted; Security that it will be essential to secure the secrecy and integration of the information. It should be low-cost; it allows widespread installation which distribution network.

With consider to the wanted requirements in the introduction section, authors proposed a combined simulation - computation method to upgrade the present smart grid control, monitoring and protection system. The following sections are showing the methods and a typical modeling to restoration by a reconfiguration of distribution medium voltage network.

**III. Modeling a typical network with economical evaluation**
A Simulated model with the following design studied and results are discussed. This section includes 18 feeders including of adjacent feeders of this network. The network has 8 opened CBS. Nominal voltage is 20 kV and the maximum allowable voltage drop in the network is equal to 5 percent.
Method of performing load flow backward-forward, before performing optimizing aimed at reducing losses is shown in Table 1.

<table>
<thead>
<tr>
<th>Open indexes</th>
<th>Losses (kW)</th>
<th>Load balancing index</th>
<th>Maximum voltage drop in branch</th>
</tr>
</thead>
</table>

As can be seen, the loss before performing system reconfiguration, based on the maximum amount of load buses, is 63,9636kW.

Fig.: Studied network, modeled in Digsilent environment.
To consider a load balancing index for the whole system, the appropriate parameters must be defined as a measure of load balance in \( i \) branch. This index is indicative of how the branches are pregnant. For this purpose, a parameter is defined as follow:

\[
\text{Line Usage Index} = \frac{S_i}{S_i^{\text{max}}}
\]

Where: \( S_i \) is Apparent power at the sending bus of branch \( i \) and \( S_i^{\text{max}} \) is defining its maximum capacity (MVA). The index measures the load balancing problem can be presented as follows.

\[
X = \left[ \frac{S_1}{S_1^{\text{max}}} \frac{S_2}{S_2^{\text{max}}} \cdots \frac{S_i}{S_i^{\text{max}}} \cdots \frac{S_n}{S_n^{\text{max}}} \right]
\]

\[
LBI = \text{Var}(X)
\]

Also according to equations (4) and (5), load balancing index is 0.74 and maximum system voltage drop is 1.04 percent.

Load flow results after reconfiguration with aim to improvement of load balancing and loss reduction and to define the limits a typical feeder in a forward backward approach has been done. Also voltage profile of the network after optimization is shown in Fig 13 and results of computation are shown in the table 2. These calculations are based on full load time of the network has been done.

<table>
<thead>
<tr>
<th>Open indexes</th>
<th>Losses</th>
<th>Losses reduction</th>
<th>Load balancing index</th>
<th>Improving load balancing</th>
<th>Maximum voltage drop</th>
<th>Improving the maximum voltage drop</th>
</tr>
</thead>
<tbody>
<tr>
<td>372-31.1</td>
<td>57,8298</td>
<td>%11,89</td>
<td>0.72369</td>
<td>%4</td>
<td>%0.59</td>
<td>%56.73</td>
</tr>
<tr>
<td>376-366</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>369-368</td>
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<td>334-333</td>
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<td>332-333</td>
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<td>320-323</td>
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<td>318-319</td>
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<tr>
<td>340.1-370</td>
<td></td>
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</tbody>
</table>

As shown in Table 2, to perform reconfiguration, with reducing 11.89% network losses, from the 63/965 kW to 57/82 it has.

Maximum voltage drop with a 56% recovery rate, from 1.04 reach to 0.59. Also, the feeder load balancing in different branches has been associated with an improvement of 4 percent.
In order to implement the algorithm with the system restoration, at the first it is needed to introduce a fault point in the distribution network.

The opening and closing of the CBs in order to restore the system at sample points in the system has been shown in the table (3). Improving the reliability of the distribution network algorithm is used to perform the modeling.

In order to implement the algorithm with system recovery, the need to introduce the fault occurrence point in distribution network is desired.

The opening and closing process of circuit breakers at the sample points, in order to system restoration, that applied by algorithm of improving the reliability of the distribution network on a sample feeder is shown in the table (3).

<table>
<thead>
<tr>
<th>Table (3): The opening and closing process on several sample faults</th>
</tr>
</thead>
<tbody>
<tr>
<td>292-291</td>
</tr>
<tr>
<td>459/4</td>
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</tbody>
</table>

In this table, the lost loads per four different faults in different parts of the network are displayed. In all these cases, if there is another path to system restoration, with passing the first stage, all lost loads are restored.

Later, in order to optimizing the network structure switching is done when the fault occurred.

Thus, as can be seen in the later stage, switching is led to improve the network losses and the maximum allowable voltage drop of the networks.

This improvement is due to transfer and distribution of no fed feeder loads at the network level and in the most efficient and possible way.

IV. Economic analysis results
At the studied networks, the losses rate in the low-load seasons is equal to 41/8664 kW and in full load seasons is 63/9536 kW.

The value of the losses in a given day, with the official rate of electricity RLS 773 per kWh for low load season is equivalent of RLS 776,705.
For full load season is  RLS 1216150. Then average annual value of losses is equal to 364 535 692 rials.

Table 4: Calculation of savings due to reduced losses

<table>
<thead>
<tr>
<th>Average annual (RLS)</th>
<th>The dissipated energy in a day (RLS)</th>
<th>The dissipated energy per year (RLS)</th>
<th>The dissipated energy in a month (RLS)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>364 ,535-692</td>
<td>288934428</td>
<td>24077869</td>
<td>776705</td>
<td>low load seasons</td>
</tr>
<tr>
<td></td>
<td>452407944</td>
<td>37700662</td>
<td>1216150</td>
<td>Full load seasons.</td>
</tr>
<tr>
<td>321 ,227-758</td>
<td>250916805</td>
<td>20909733</td>
<td>685565</td>
<td>low load seasons</td>
</tr>
<tr>
<td></td>
<td>392599650</td>
<td>32716637</td>
<td>1072676</td>
<td>Full load seasons.</td>
</tr>
<tr>
<td>42-777-465</td>
<td>38017623</td>
<td>3168136</td>
<td>91140</td>
<td>low load seasons.</td>
</tr>
<tr>
<td></td>
<td>59808294</td>
<td>4964025</td>
<td>143474</td>
<td>Full load seasons.</td>
</tr>
</tbody>
</table>

As can be seen, annually average value of not dissipated energy is equal to RLS 42,777,465.

It is noteworthy that the achieved numbers just do rearrangements result on one of the city distribution network feeders (feeder section 8).

Obviously, applying this method on the rest of the network, as well as its economic value will increase.

In this paper, a new approach aimed at reducing losses and improving the rearrangement of load balancing in distribution networks was presented.

In this regard, the ant colony algorithm was used to make a wide search space.

The used optimization function is a multivariate function with fuzzy variables.

Simulation results show that the performance of the proposed method on two networks, a new structure for CB state found, that not only the losses optimally reduced but also the balance of load improved in a well shape.

The voltage drop is reduced to its minimum. These results indicate the ability of proposed algorithm in solving of distribution network rearrangement.

Due to system restoration, table (7) shows the total savings at the end of each stage of the process, including switching in the last stage, has been calculated.

During the operation, the improvement of the network, it will be possible to operators that with knowledge of the technical and economic status of the network at fault, the best choice is made.

Finally, this method consider to shortening of the electrical network outages due to faults. The factor is considered as one of the most important parameters of the reliability of the network.
### Table 7: Economic Evaluation of power losses in the recovery operation.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Methodology</th>
<th>Net loss in normal operation mode (kW)</th>
<th>Added losses (kW)</th>
<th>Added losses costs (RLS)</th>
<th>Savings due to restoring (RLS)</th>
<th>Total savings (RLS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1</td>
<td>Closing the CB to feed the isolated maximum load</td>
<td>370 - 337</td>
<td>10.41</td>
<td>6909.300</td>
<td>5820.120</td>
<td>9190.260</td>
</tr>
<tr>
<td>Stage 2</td>
<td>Closing the CB (create loop)</td>
<td>312-320</td>
<td>320-309</td>
<td>79.10</td>
<td>8.42</td>
<td>320-309</td>
</tr>
<tr>
<td>Stage 3</td>
<td>Closing the CB (create loop)</td>
<td>320-323</td>
<td>312-309</td>
<td>76.67</td>
<td>64.87</td>
<td>320-309</td>
</tr>
<tr>
<td>Stage 4</td>
<td>Closing the CB (create loop)</td>
<td>318-319</td>
<td>76.48</td>
<td>76.67</td>
<td>64.87</td>
<td>320-309</td>
</tr>
</tbody>
</table>

### V. Conclusions

Research on power system simulation and analysis tools is now facing new and major challenges: Simulation of extremely large networks, very complex networks, penetration of renewable energy and Smart Grids. New trends and means for solving increasingly complex problems are performed by Parallel computations, Cloud computing, Collaborative computing, Advanced visualization methods and Data portability with CIM. To combine a simulation method with numerical and computational technique help to have a more string smart grid. Robust algorithm is needed to analysis of several reconfigurations of networks. CBs maneuver help to get better restorations. To merge the methods a powerful algorithm with most strong software is needed. Authors tried to combine the simulation and computational methods to introduce a new face for smart grid system configuration.

In this paper, a new approach by rearrangement aimed at reducing losses and improving of load balancing in distribution networks was presented.
Simulation results show that the performance of the proposed method on two networks, a new structure for CB state was found, that optimal reduction of losses and load balancing in the lines has been improved in a desired shape. Economical, reliability index and technical tools are used to get a full and complete analysis.

VI. References