Assembly of GIS information to compile the interconnected graph of the European electricity and gas network

F. Bono
Joint Research Centre, Ispra - ITALY

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Motivation

Critical Infrastructures

- Electricity
- Gas

Hazards

Complex System
- HV grid
- Gas pipeline disruptions
- Vulnerability
Approach

Mathematical Methods

Fragility Curves

Adjacency Matrix

Graph Network
Overview

• Introduction
• Geographical Information Systems (GIS)
• GIS and networks
• Data processing issues
• The EU interconnected energy network
Introduction

- The recent improvements of GIS has led to the acquisition of massive data sets on territorial and infrastructural elements (transportation, utilities and social networks with a geographical component) that were previously unavailable.

- Georeferenced data are a precious commodity that allows us to compile and study man-made networks, provided that a convenient preprocessing of the data is performed.

- GIS data mining and processing methods to effectively combine heterogeneous data sources into meaningful real-world networks are presented, with an insight into the problems and solutions adopted within the ManMade project.
A geographic information system (GIS) integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information.
Vector data model. Discrete features, such as infrastructural elements, are usually represented using the vector model.

Raster data model. Continuous numeric values, such as elevation, and continuous categories, such as population distribution, are represented using the raster model.
GIS and Network Analysis

SQL database

Georeferenced network data (GIS)

Network Analysis Software (Pajek)

Mathematical computations (Matlab)
GIS and networks

- GIS Network Analysis basic functionalities
- Topology issues
- Generation of interconnected networks from disjoint GIS data
Topology Issues

GIS

Networks

Map Images georeferencing

Network Analysis

- Nodes degree
- Strong Components
- Loops
- Closed Cycles
Relating network elements

GIS

gas and electricity networks
Condensing the network

- Working with networks at continent level
- Focus on major networks
- Relating objects connected via the minor network
Shortest path (red line) between a power plant and the substation on the main network; the geographically closest substation is not the one to be associated with the plant.
Virtual Edges

Breadth first search of the shortest paths between a power station and the substations on the main network.

a) Substation (target nodes)
Main network
Shortest path 1
Power plant
Shortest path 2

b) Virtual edges
Setting the hazard level on the networks’ elements

SOURCE: The Global Seismic Hazard Assessment Program (GSHAP)
Gas Sources

LNG Terminals
Natural Gas Production Regions
Natural Gas Producing Countries
Open Sea gas nodes
The original electricity grid dataset is composed of transmission lines and substation of the whole Europe.

The problem to distinguish between the nodes serving the distribution network and those that belongs to the high voltage transmission lines only, led to the definition of a set of rules in the GIS.
In order to evaluate the population affected in case of hazard-induced damages to the electricity network, the customers served by each distribution substation was computed.

The number of customers is computed generating Thiessen polygons for the distribution substations.

Thiessen polygons define individual areas of influence around each set of points; each polygon therefore defines the served area of each substation.
Generation of adjacency matrices

1. GIS data extraction
2. Network grid compilation (ID_from, ID_to, value)
3. Matlab and Pajek data import and processing
4. GIS import of computed values
The interconnected Network

Gas pipelines
2212 nodes
2644 edges
75 Arcs
21 LNG terminals

Electricity grid
5127 subs
6726 edges

Power plants
998 Natural Gas
4383 Others

Directed Network

- Gas Sources
- Gas node
- Power Plants
- Subs