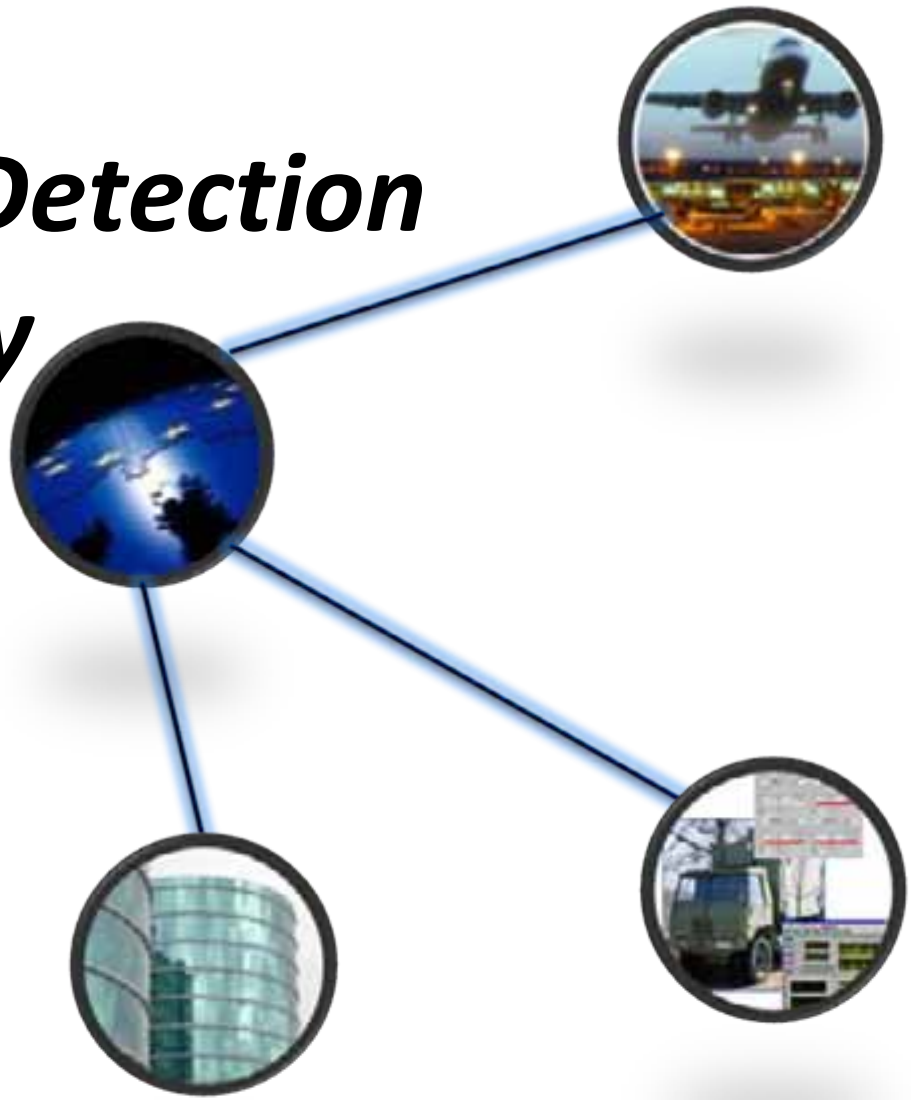
PLUSONEMINUSONE

Power Grid Island Detection Using Graph Theory



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Boğaziçi University
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PLUSONEMİNUSONE ENERGY

About P1M1

- R&D Organization building software on GIS based solutions. www.p1m1.com
- Located in Boğaziçi University Campus
- All algorithms are developed in-house
- Location based forecasting and optimization solutions
- Finance, Telecom, Logistics, Energy, Defense, Health and Airlines

The Team

- 13 Software Engineers, 8 Ph.D. Level Researchers (Computer Science, Electrical Engineering, Math and Geography fields), 5 Senior University students, 3 MS Students composed of electrical engineers, industrial engineers and software engineers.
- Vast Experience in GIS based optimization
- ORACLE as Database Partner
- In-depth experience at Oracle based Integration
- ESRI as GIS partner
- Intel as Processing Partner

INTRODUCTION

- Power distribution is critical in terms of input/output relationships since it is very hard and expensive to store energy.
- In order to prevent network-wide black-outs, or very fast power price increases, a power distribution network should be separated into islands. Islands are defined as geographically and energy input/output almost-isolated group of nodes. Once they are identified, they can be disconnected safely from the other parts of the network in the event of a problem.
- Also, island based energy pricing can be set. However, as the number of nodes increase, the fast detection of islands becomes harder. PlusOneMinusOne uses, graph theory and ArcGIS in order to effectively separate the islands.
- On the other hand, islands of the future are important as well. PlusOneMinusOne uses the underlying GIS and demographic information in order to estimate the future state of nodes and islands

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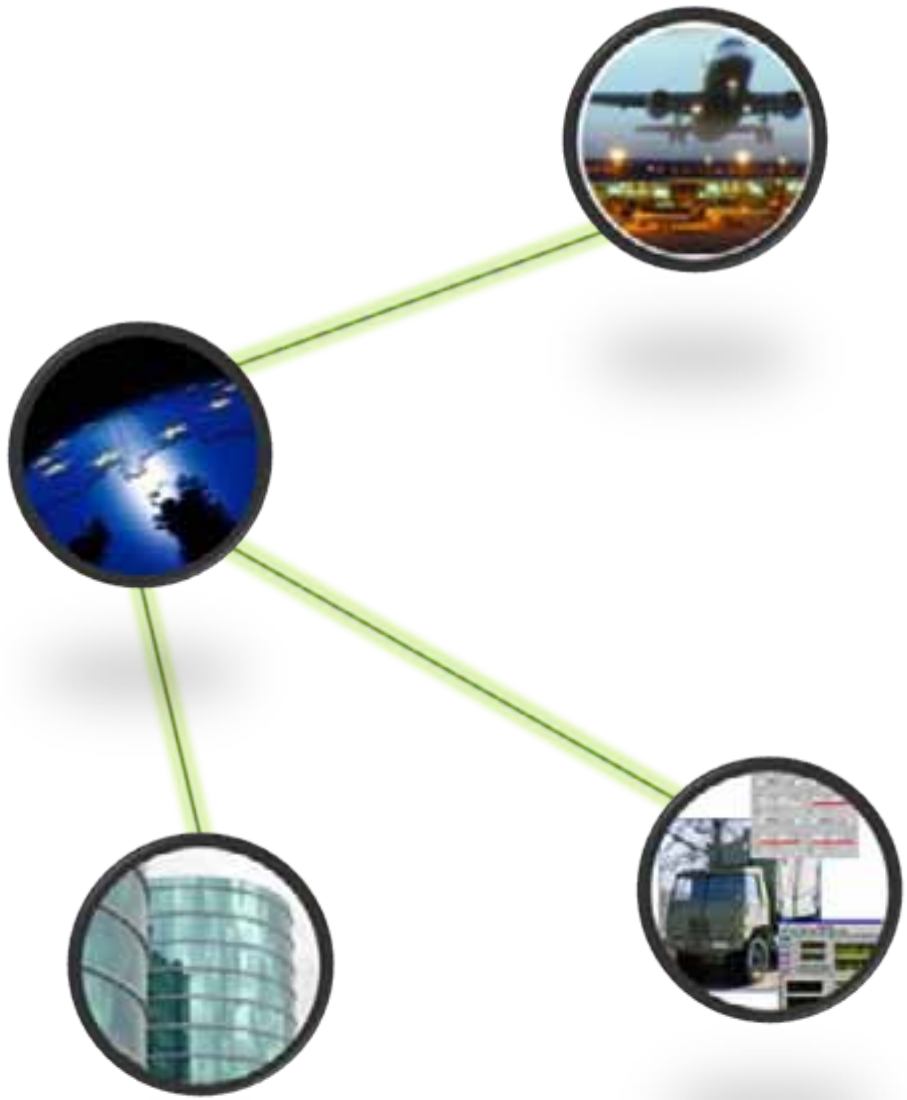

Nodes on a map

GRAPH THEORY

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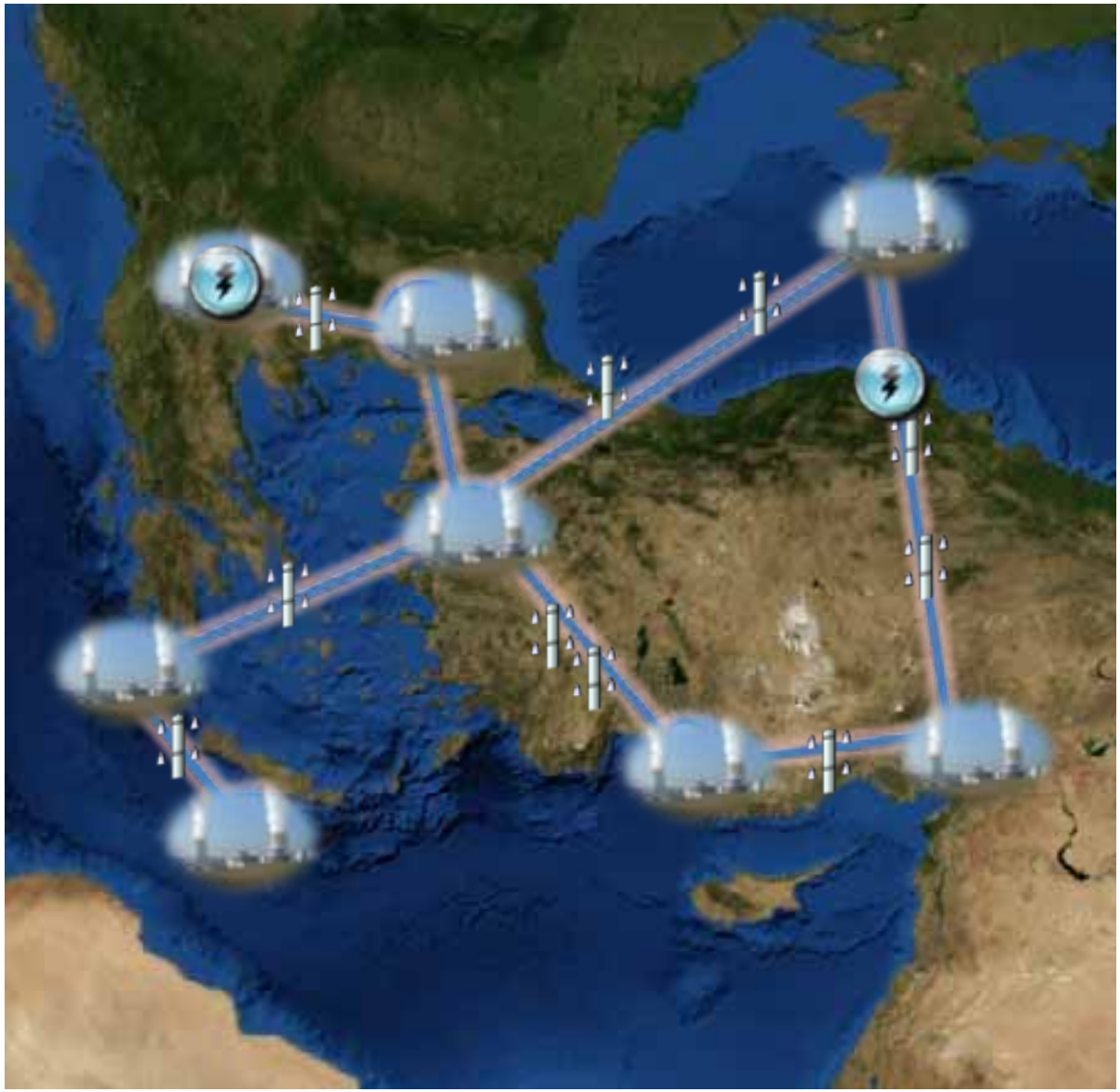
ENERGY

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Pınar
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İstanbul Çevre Yolu
Rüzgarlıbahçe
Fatih
Akatlar
Rumelihisarı
Anadoluhisarı
Etiler
Bebek
Büyükdere Cd
Atatürk Cd
Gürsel
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Airlines, Finance, Energy, Telecom

VARIOUS P1M1 SOLUTIONS

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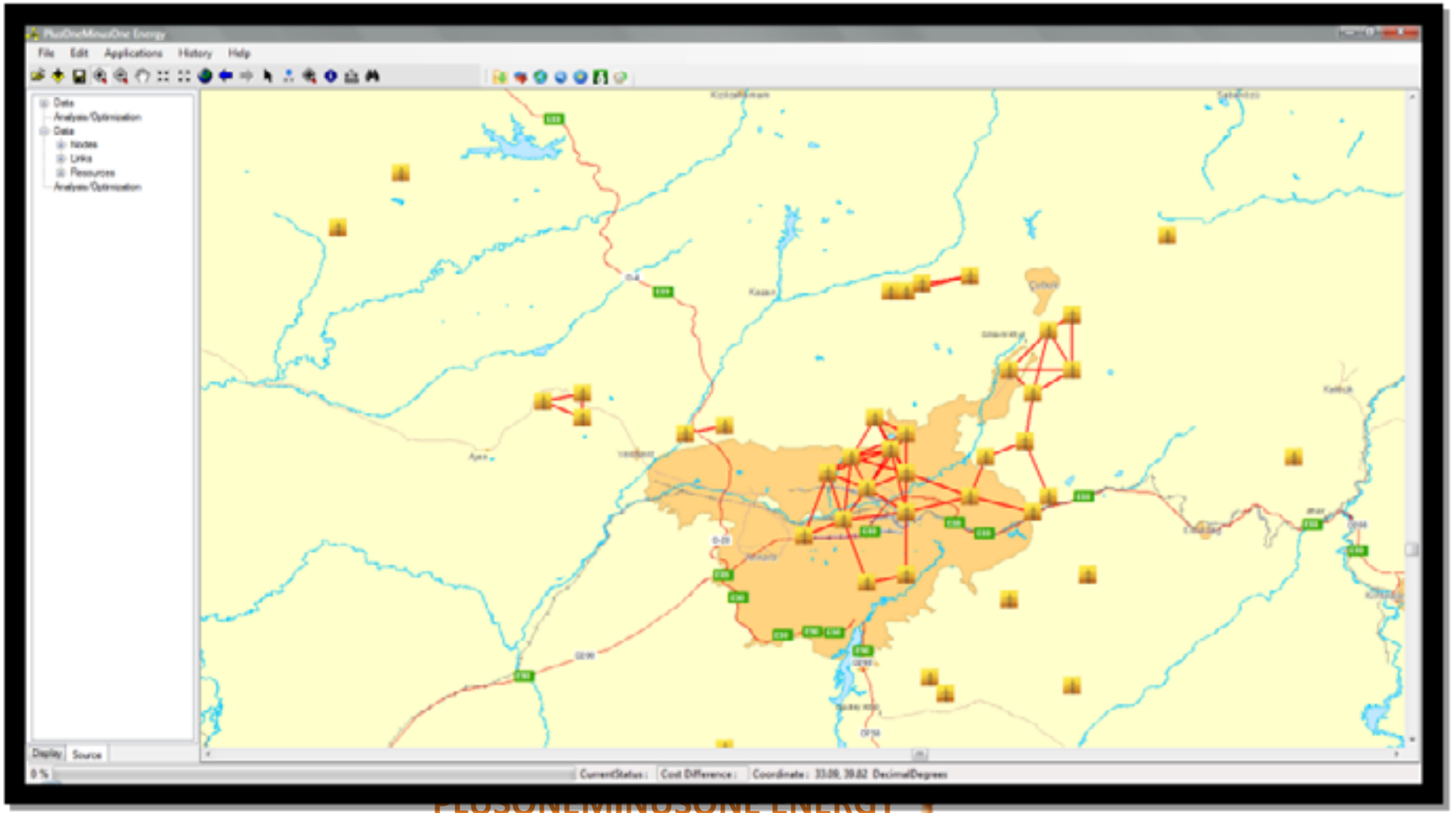
P1M1 AİRLINE

P1M1 FINANCE

P1M1 ENERGY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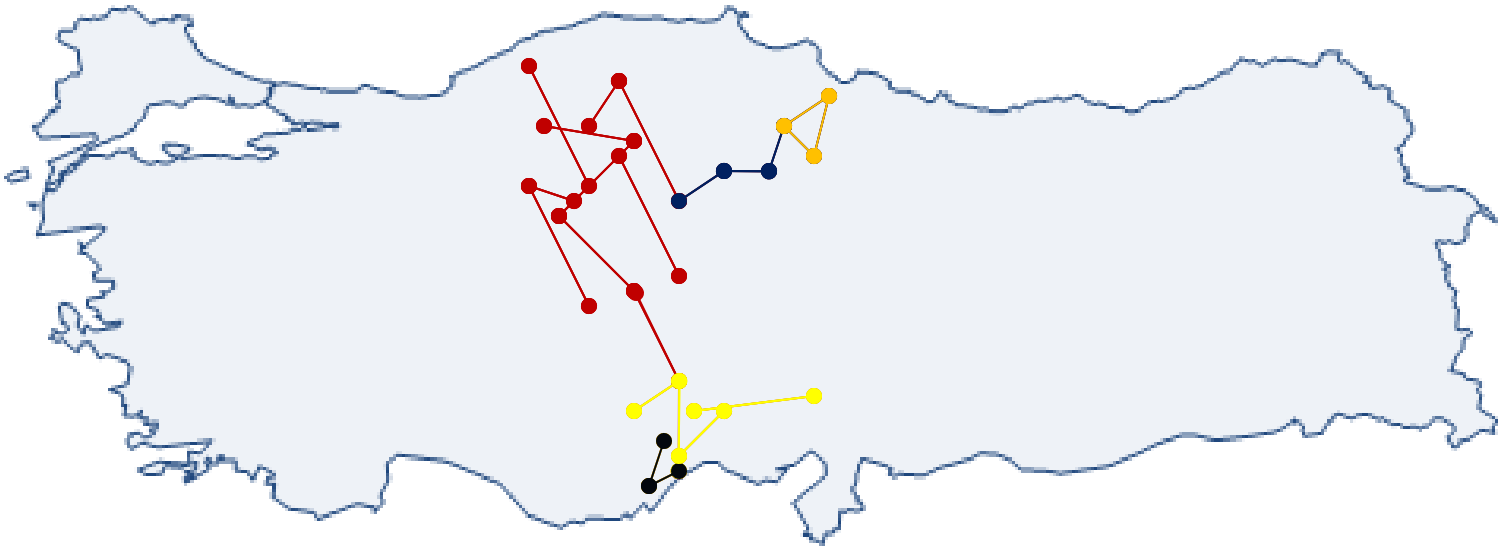
Problem Definition - I

- Electrical Island: An electrical network in a certain geographical area such that the input/output power flow to the area is marginal compared to the total flow within the area itself.
- The power distribution networks can be divided into electrical islands
  - Either intentionally or unintentionally.
- Islands, may be sufficient with their power supply-demand structure in steady state conditions. An island is tightly connected within, making it prone to total power shortage effects.
  - This may result in urgent power demands that will potentially spike the price of electricity within that region.

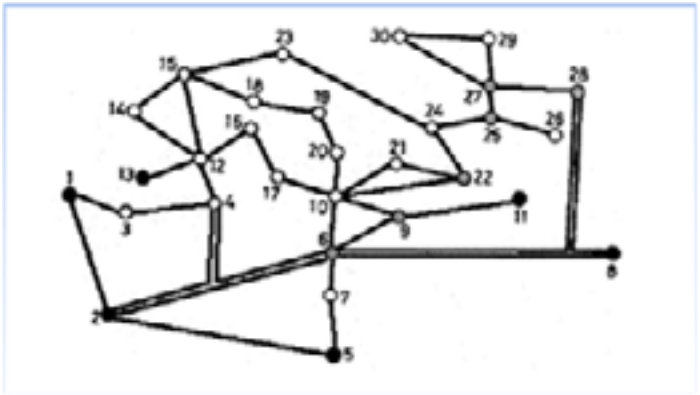
THE PROBLEM –
identify those regions before hand so that the supply-demand curve movements within these islands can be turned into profit

Problem Definition -II



Problem Details

- The problem is known in the literature as graph partitioning problem with weights.
- It is NP-hard to find every island in the network.
- Certain criteria to form an island should be set to limit the solution space.
- Possible partitioning strategies for the simple network below (*) is around 2.2 trillion
- We will not be adding new islands, however do need to check all connections to check whether there exists an island or not.



(*) IEEE 30 Bus Network

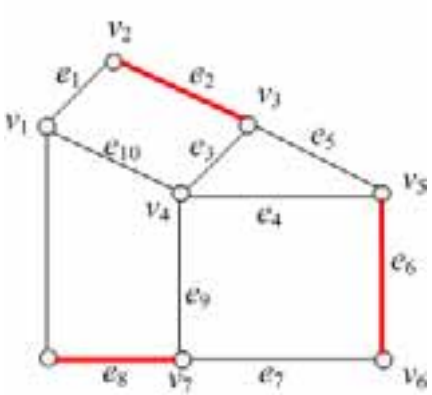
Literature Overview

- The islands are utilized for dividing the network to more manageable, self sufficient parts for distributed data management, network insurance and privatization
- Existing research can be classified into two groups with different goals;
  - GOAL-1. Optimize the network such that islands are only at pre-determined locations
  - GOAL -2. Investigate the potential cut-off points during the event of a total network break-down.

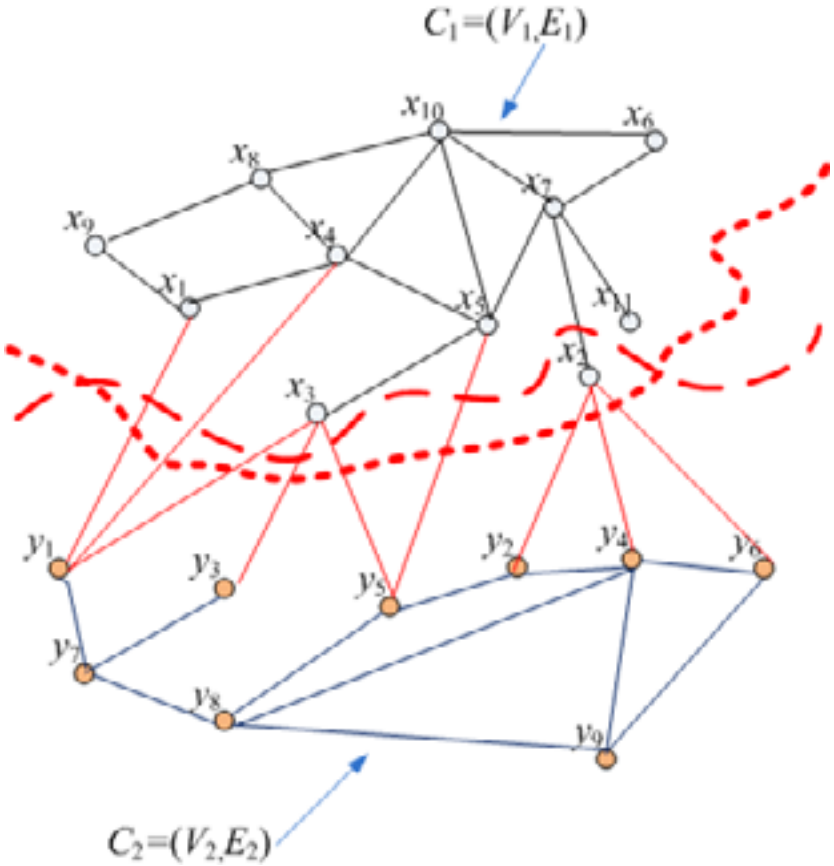
Solution - I

GRAPH PARTIONING METHOD FOR DISTRIBUTED AND PARALLEL OPTIMAL FLOW

- The idea is to divide first into random groups, than minimize the number of neighborhood between sub graphs
- Repeat until convergence
- Fast solution
- Unlike the problem under investigation, this does not include the weights in the graph



Existing Solution - I



Existing Solution - II

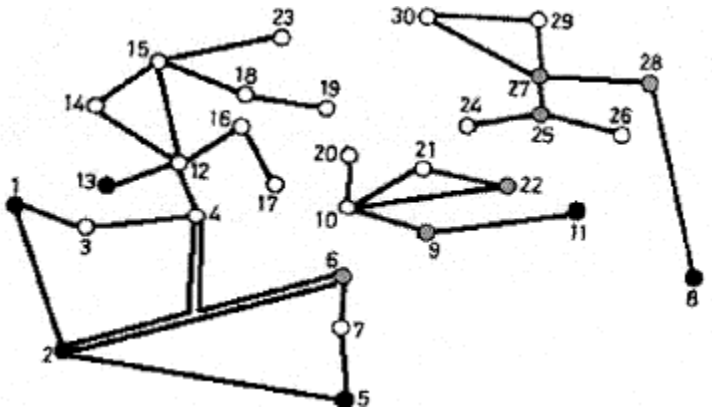
SYSTEM SPLITING STRATEGIES FOR ISLAND OPERATION OF POWER SYSTEMS

- This solution is node weighted.
- There are 3 requirements for system splitting:
  - Separation and synchronization constraint
  - Power balance constraint
  - Rated value & limit constraint
- Most important constraint is:

$$\left| \sum_{v_i \in V^u} w_i < d, \quad u = 1,2,...,U \right.$$

Existing Solution - II

- Potential time savings approach
- Some nodes can be combined to reduce complexity when computing
- The major short coming comes from the constant limit ‘d’ for all islands
  - This results in multiple solutions that should be eliminated manually.



Solution III

- We have modified the second methodology
- We replaced constant ‘d’ as a percentage of the interior flow of the potential island
- Utilized in-house developed island detection algorithms.

$$\left| \sum_{v_i \in V^u} w_i < d, \quad u = 1,2,...,U \right.$$

$$d = a \sum_{u_i \in \forall^u} |w_i|$$

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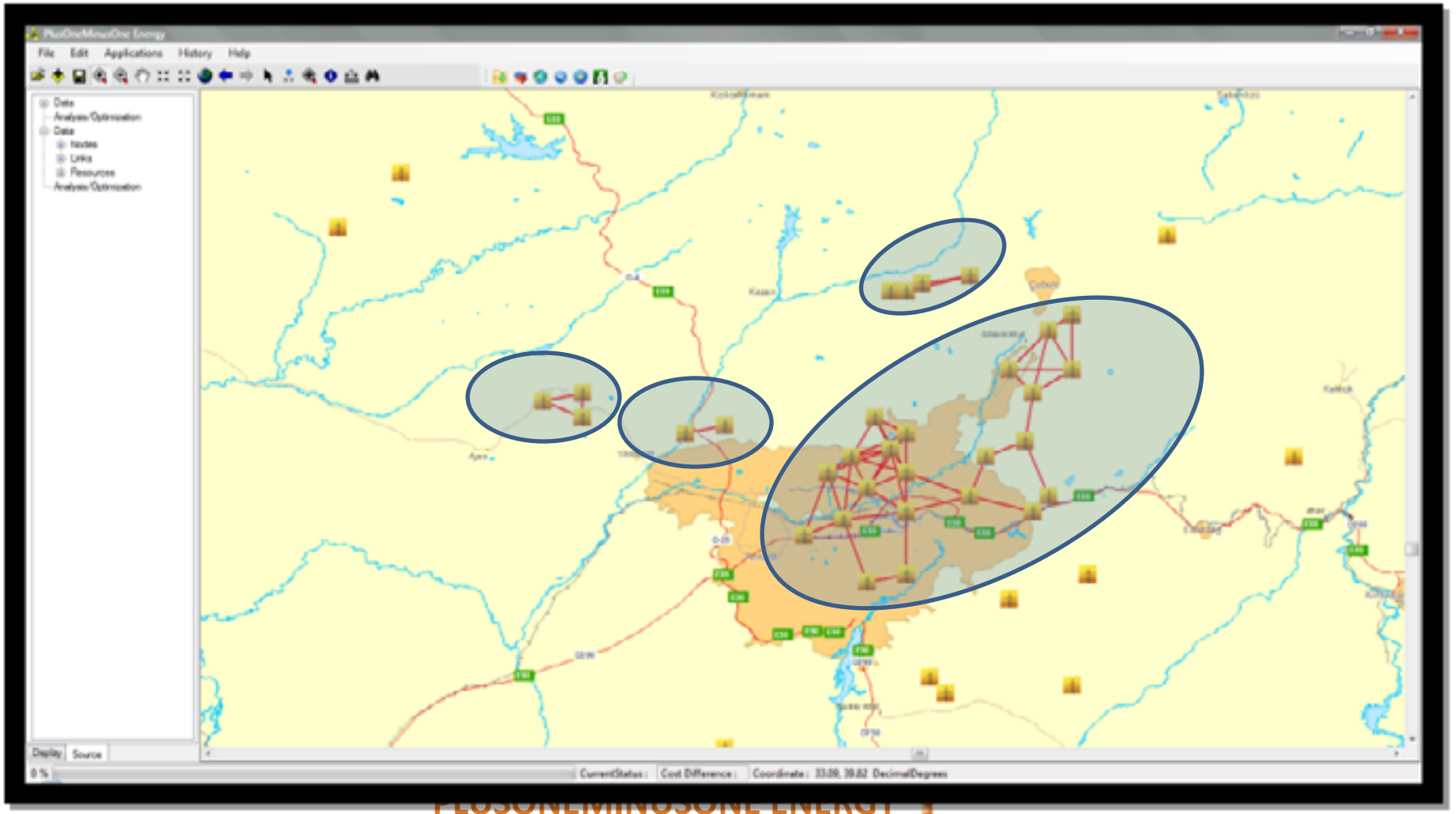
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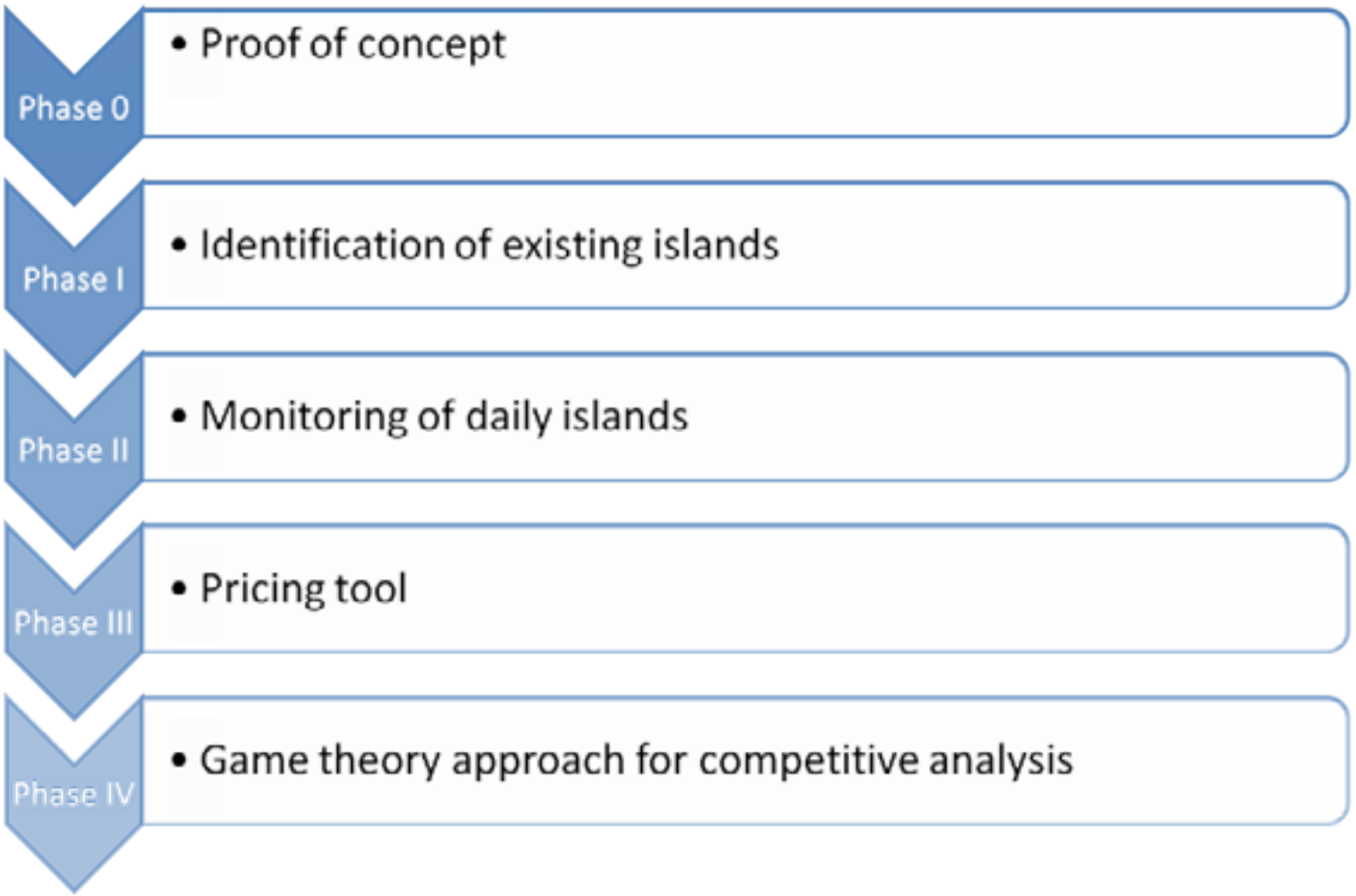
Solution Phases



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