Optimal Flow Modeling in Electrical Power Distribution :

with focus on the integration of intermittent renewable generation in the future

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Introduction

Optimal Power Flow (OPF)

- is the optimization problem of choosing dispatch of generation while accounting for the constraints of the transmission network .
- Is subject of the physical constraints imposed by electrical laws and engineering limits on the decision variables.
- Can be applied to long-term transmission network capacity planning to minute-by-minute adjustment of power dispatch.
- Is mainly guided by the characteristics of the flow of power transmitted from the generators to the loads.

Why OPF?

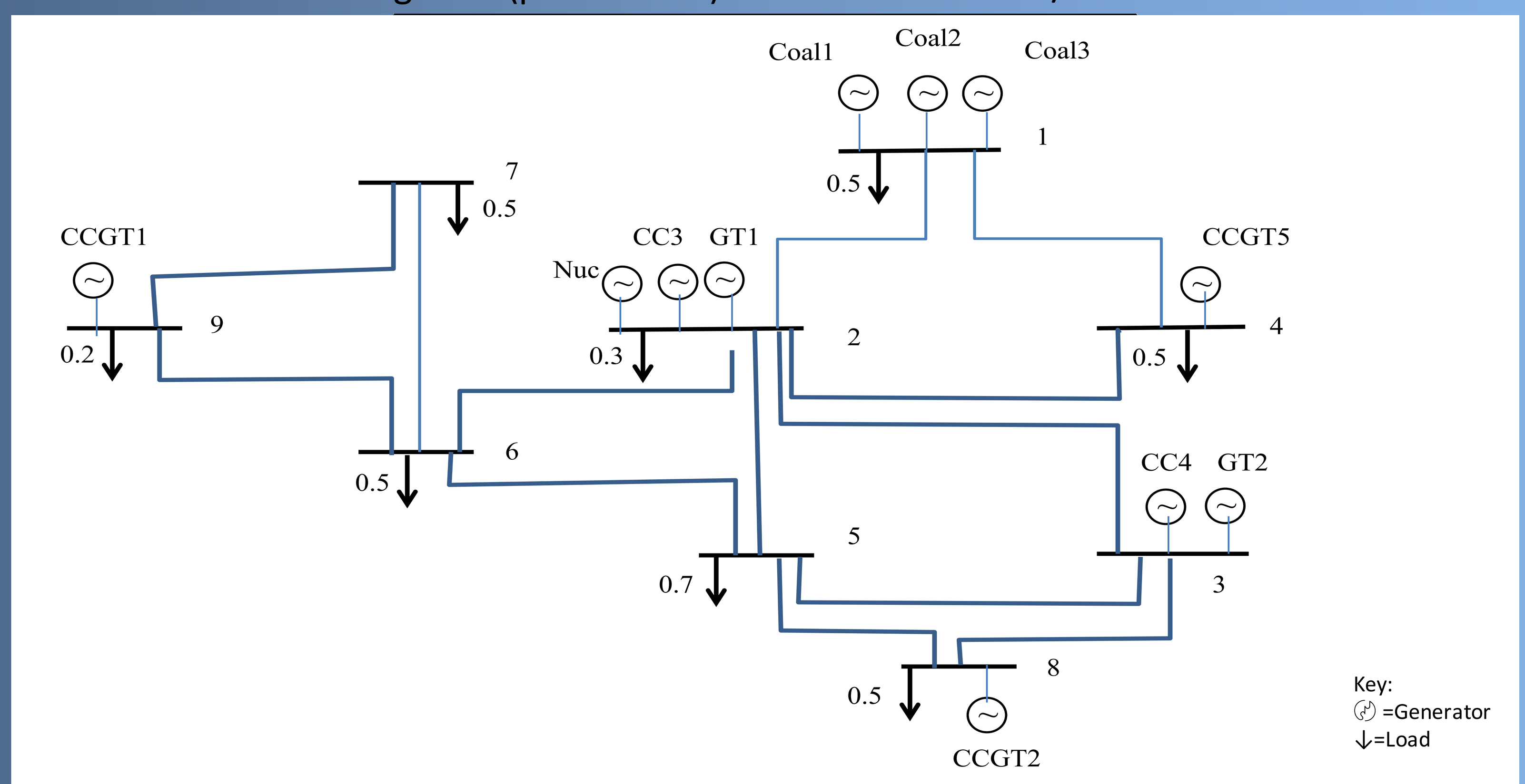
- It helps us meet the ever changing power demands minimizing cost/emissions of carbon dioxide/ use of water in power plants.
- It helps us accommodate renewable and standby power sources in a way that is economically and practically convenient and reduce pressure on power plants in times of high demand.

How?

- Using OPF modeling in GAMS to find the optimal solution using different objective functions

Data and Methodology

The following is a Model of sets of interconnected generators and loads to be used as an example. The points at which the generators and loads are connected are called nodes and are numbered, where as the connecting lines (power lines) are called branches/arcs.



Data from the Image above and data with given Impedance values is written into the GAMS model as parameters and sets

The OPF is solved subject to the following constraints

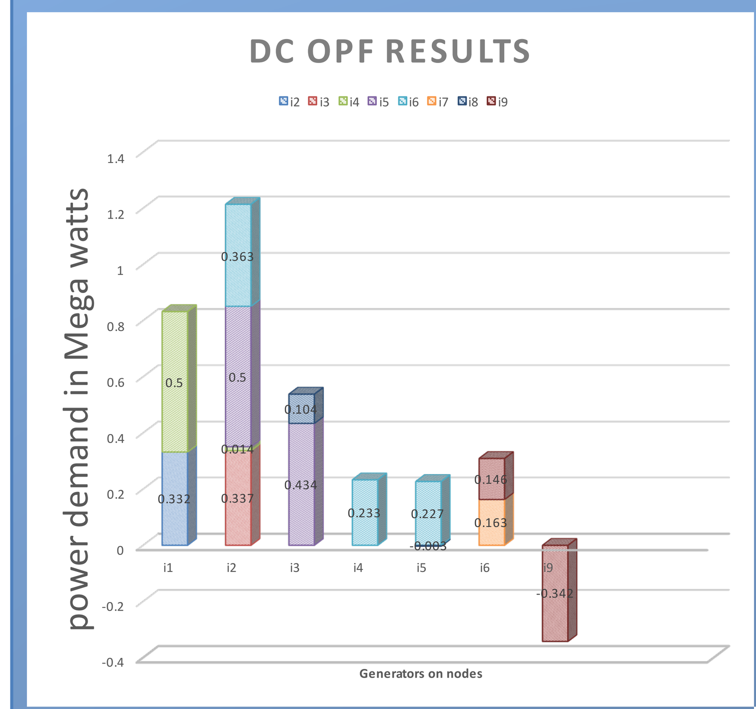
- Minimize total Cost (Objective Function)= Cost of Operation + Cost of Generation at each node
- Supply = Demand
- Power Flowing from each Node = Power Generated – Load
- Alternating Current (AC)/ Direct Current (DC) power flow equations
- Minimum and Maximum Generation Levels

The output for the model is the Real and Reactive Power at each node (AC), the Voltage at each node (AC), the angle of Phase Difference i.e Theta, and the Power Flowing from One node to another (DC).

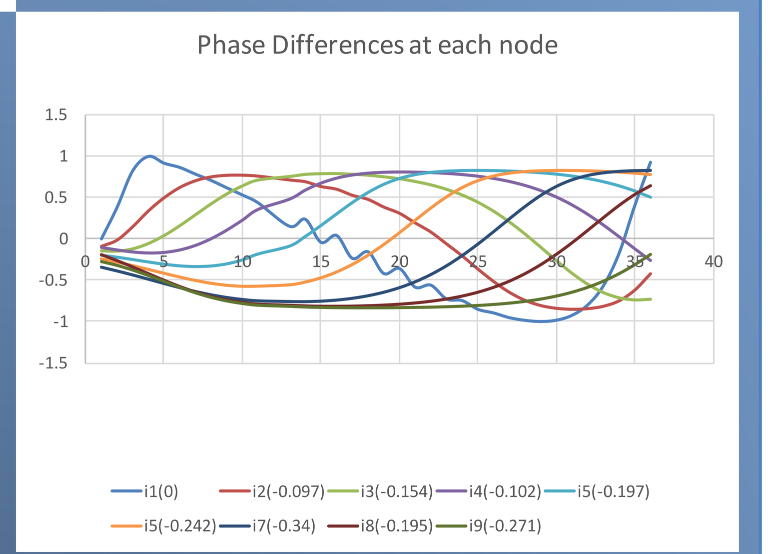
Results

Two models of the same example in the previous section were run in GAMS one as AC OPF and another as DC OPF

DC OPF

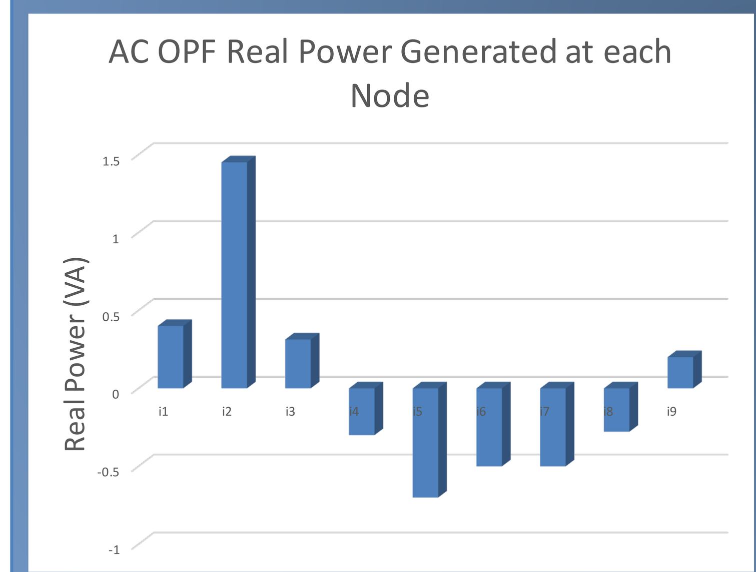


Graph shows the amount of power generated at each node and the amount supplied to other different nodes in the system.



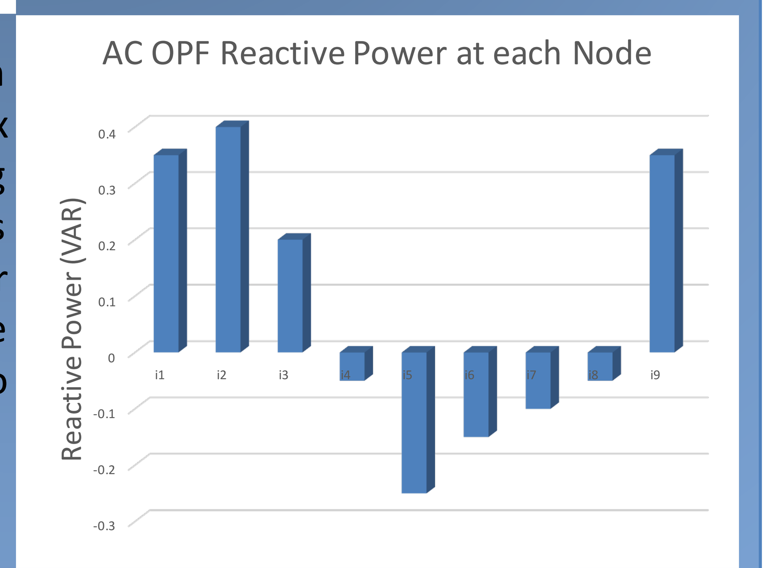
Graph illustrates the phase differences in the flow of current with reference to node 1 which is fixed at zero.

AC OPF



Graph represents Real Power at each node and it observed that nodes with more generators than loads have a positive sign on the power.

Graph shows reactive power at each node. Reactive power is the complex component of power in alternating current which attributes to the changes in direction of the current. All the power graphs show that node 2 supplies more power since nuclear power is cheaper to produce.



Node	Voltage (V)✕100
i1	1
i2	1.015
i3	0.991
i4	0.979
i5	0.963
i6	0.959
i7	0.95
i8	0.95
i9	0.993

The table shows the voltages at each node and there is very slight differences in the values since the supplied voltage should be similar to the voltage value of the electrical appliances at the load.

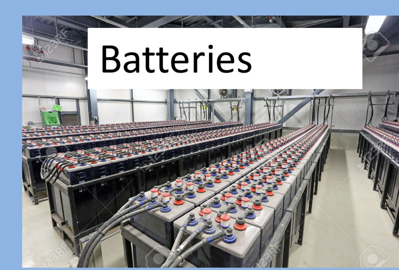
Conclusion

Modeling the OPF in this way is helpful because:

- It tells us the cheapest way of supplying electricity to different places
- It tells us which generator to use at a given time and which one to save for another time thereby saving the amount of electricity lost.
- Storing electricity is very expensive therefore a lot of money is saved if the demand of electricity is satisfied easily.
- It can be easily adjusted to solve any other similar problems.
- It works in long term transmission therefore you can give solutions to problems that will be faced in ten years from now.
- Objective function can be changed so as to minimize anything other than cost.
- Renewable source of electricity can be accommodated in the system so as to reduce pollution.

Future Work

- In an effort to reduce carbon dioxide emissions caused by the power plants cleaner sources of energy like wind and solar energy can be used instead of nuclear and gas.
- Lower voltage systems which can easily include these cleaner energy sources have to be developed.
- Building from this high voltage OPF model, other models including solar panels, wind mills and batteries are to be designed.
- This will not only help to reduce the amount of carbon dioxide emissions but it will help out in meeting the ever increasing demands of electricity by providing alternative power sources.



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Reference

"A Primer on Optimal Power Flow: Theory, Formulation, and Practical Examples" By Stephen Frank & Steffen Rebennack.