Reliable operation of hybrid AC/DC power systems in different time frames under uncertainty

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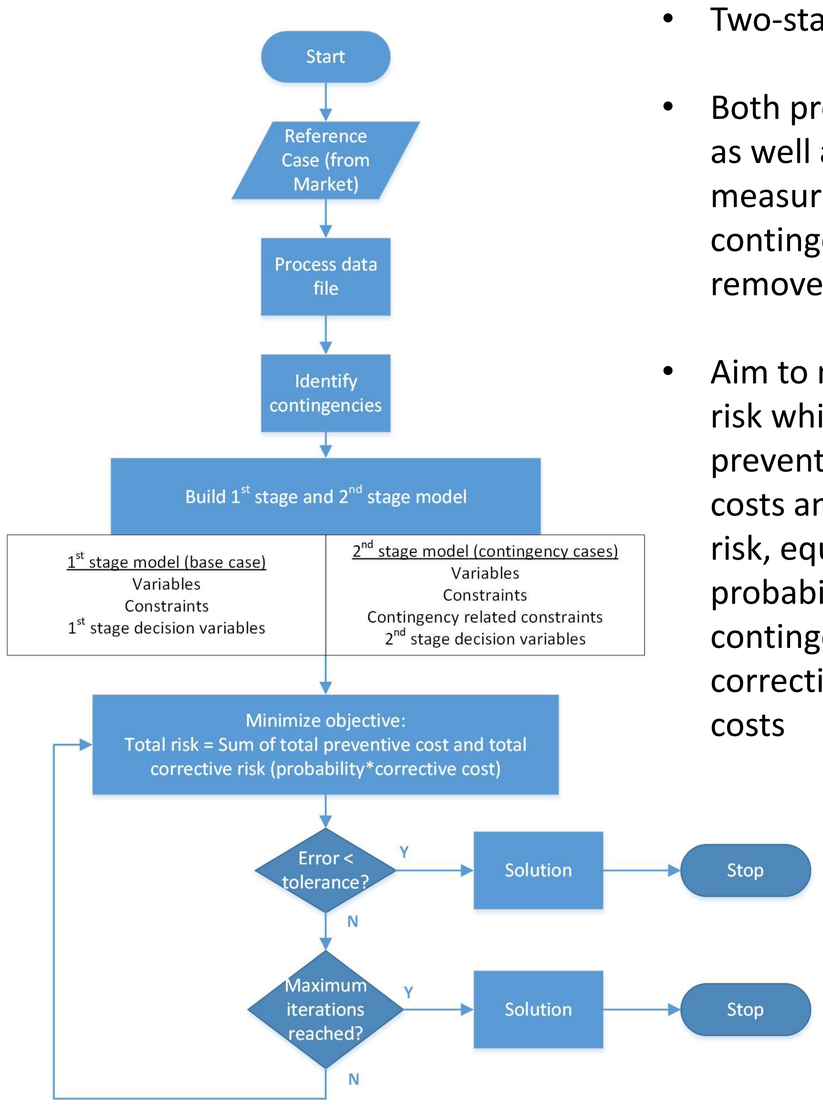
Background

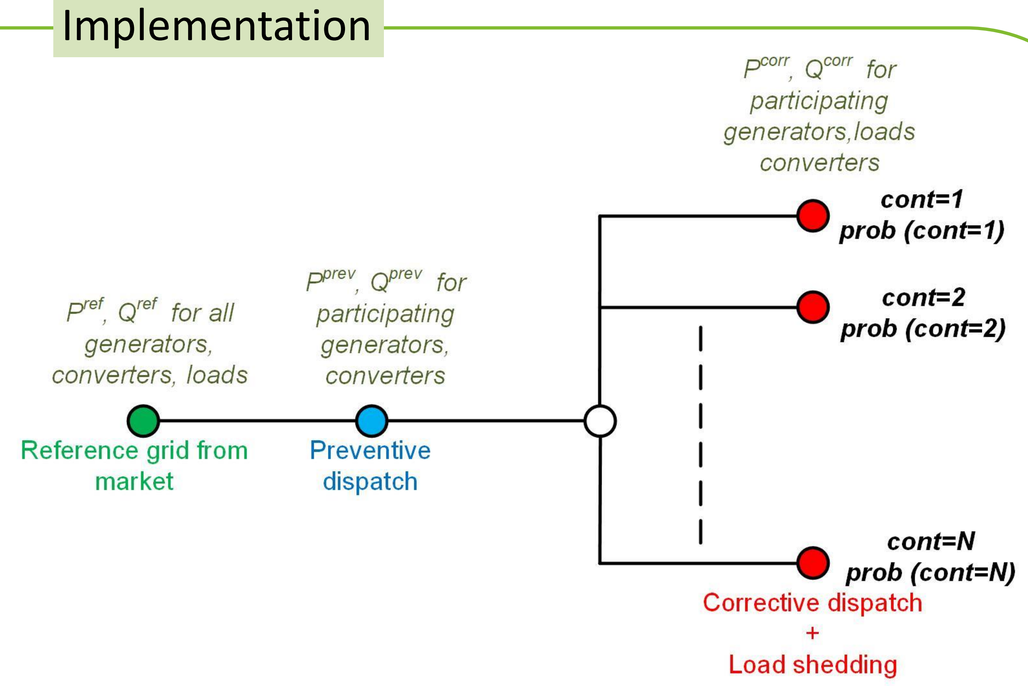
- Present reliability assessment based on deterministic N-1 criterion does not capture the actual likelihood of contingencies.
- With increased penetration of the renewable energy sources and dynamics of intra-day markets, there is an upsurge in the system uncertainties in operational time frames. Probabilistic methods are better suited to address the new situation.
- Large scale integration of HVDC into existing system and planned development of HVDC grids may be utilized to improve operation owing to characteristic flexibility of HVDC.
- Preventive-corrective security provides opportunity for trade-off between costs and risks. Thus, a 2-stage preventive-corrective Security Constrained Optimal Power Flow (SCOPF) model is implemented for AC/DC grids.

Proposed Method



- Two-stage process
- Both preventive measures as well as fast corrective measures (after system contingency) utilized to remove the violated limits
- Aim to minimize the total risk which is sum of preventive redispatch costs and the corrective risk, equated to the probability of a contingency times the corrective redispatch costs

Implementation

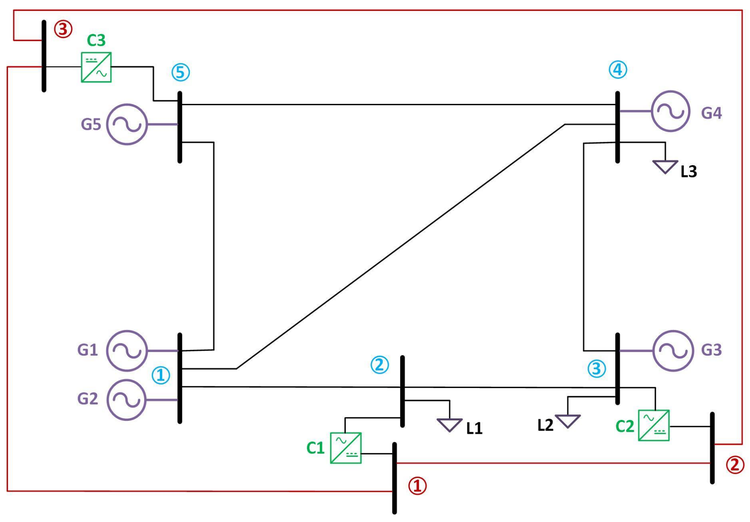


$$min \sum_{g=1}^{N_g} |\Delta P_g^{prev}|.C_g^{prev} + \sum_{c=1}^{N_c} |\Delta P_c^{prev}|.C_c^{prev} + \sum_{cont=1}^{N} prob_{cont}.\left(\sum_{g=1}^{N_g} |\Delta P_g^{corr}|.C_g^{corr} + \sum_{l=1}^{N_l} |\Delta P_l|.VOLL + \sum_{c=1}^{N_c} |\Delta P_c^{corr}|.C_c^{corr}\right)$$

First stage = Preventive actions cost

Second stage = Contingency probability * (Corrective actions + load shedding cost)

Case study



Generator	Pg (MW)	Qg (MVAr)	CostPrev (€/MWh)	CostCorr (€/MWh)
1	39,9	29,9	14	70
2	169,9	127,5	15	75
3	230,04	389,9	30	150
4	0	-27,5	40	200
5	574,6	-179,8	10	50

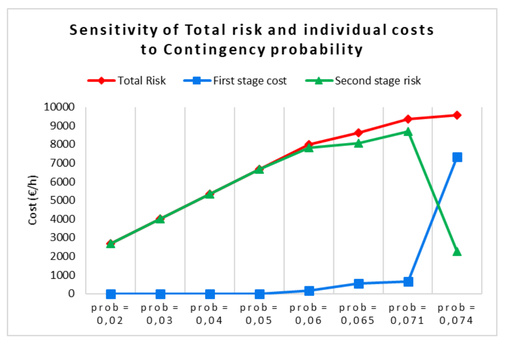
Load	Pl (MW)	Ql (MVAr)	VOLL (€/MWh)
1	300	98,6	5000
2	300	98,6	5000
3	400	131,5	5000

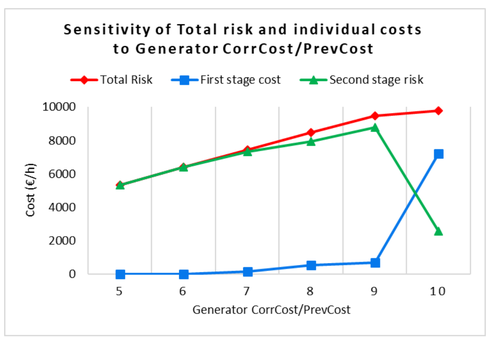
Converter	Pc (MW)	Qc (MVAr)	Pdc (MW)	CostPrev (€/MWh)	CostCorr (€/MWh)
1	5,3	-31,6	-4,2	1	5
2	-99,9	-3,4	101,3	1	5
3	100	-1,5	-98,7	1	5

Contingencies	probability
AC branch 1-4	0,005
Generator 1	0,005
AC branch 1-2 and Generator 1	0,005
AC branch 1-5	0,005

- PJM 5-bus test system as the AC grid
- 3-bus MTDC system

Results





Contingency probability	Total Risk (€/h)	First stage cost (€/h)	Second stage risk (€/h)
0,02	2663,7	0	2663,7
0,03	3995,7	0	3995,7
0,04	5327,38	0	5327,38
0,05	6659,22	0	6659,22
0,06	7977,17	167,372	7809,796
0,065	8613	551,96	8061
0,071	9350	645	8705
0,074	9579	7316	2263

- Variation in total risk, first stage cost and second stage risk based on contingency probability
- For higher probability value, cheaper to secure preventively

Generator CostCorr/CostPrev	Total Risk (€/h)	First stage cost (€/h)	Second stage risk (€/h)
5	5327,38	0	5327,38
6	6392,88	0	6392,88
7	7455,62	144,88	7310,74
8	8485,64	549,36	7936,28
9	9471,55	696,59	8774,96
10	9778,79	7214,47	2564,32

- Variation in total risk, first stage cost and second stage risk based on relative corrective cost coefficients for generators
- With increasing corrective cost coefficients, preventive dispatch is more favorable and thus higher preventive costs

Prospective steps

- Testing and validation of the implemented preventive-corrective SCOPF model for larger systems
- Consideration of contingencies in DC grid and of AC/DC converters as well as changes in generation
- Implementation of AC/DC preventive SCOPF model and comparative analysis with above model

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