## Requirements

Implement a solution for the problem of crude oil pipeline operation:

- 1. Create a population of 16 stations for petrol extraction, with 16 tanks, and 16 pumps
- 2. Initial levels of the tank is 40 percent of their storage capacity, with variance standard deviation of 10. Input per tank is 10 gallon/hour with standard deviation of 3. The pipeline total capacity is to dispatch 200 gallons per hour with all pumps turned on, each pump can on average dispatch 12 gallons per hour with a random standard deviation of 2 gallons.
- 3. Define a rule or strategy to optimize the pipeline optimization and the best time scale for simulation; try stabilized the system, with the volume of storage tank around 50 percent; simulate a dynamic 48 hours scenario. Create a solution that will reach following goals: (a) try to keep the tank levels closest to 50 percent; (b) maximize the lifespan of the pipeline; (c) minimize the electricity consumption; (d) keep the delivery flow as close as possible to a constant flow at 160 gallons per hour;

## Solution

The code consists of two parts, the simulation and optimization using Metropolis Markov chain Monte Carlo. Each simulation happens in a 48 hours duration, every hour a step can be taken to change the pump switch. To evaluate every simulation, a loss function value is calculated based upon the tank level mean error and standard deviation, total pump volume mean error and standard deviation and number of switch change. Then optimization can be done by applying Metropolis MCMC of generate a candidate x' value within the desired probability distribution then accept or reject it based on its acceptance ratio of f(x')/f(x). From the result, 1 hour interval and turning on the pipe below 50.29 percent is preferred for this current station.

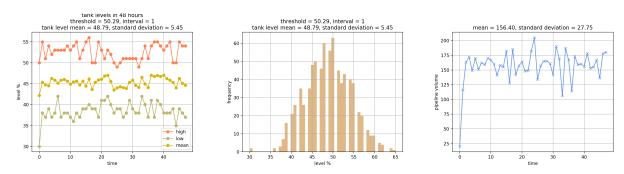


Figure 1: Simulation of 48 hours with 1 hour step interval

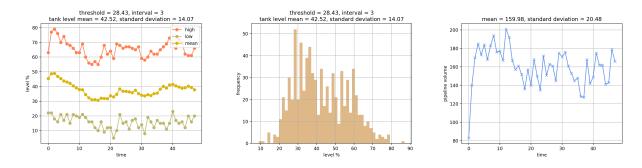


Figure 2: Simulation of 48 hours with 3 hour step interval

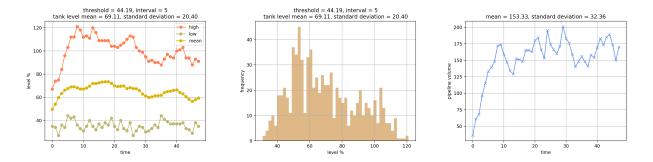


Figure 3: Simulation of 48 hours with 5 hour step interval

hour pump volume tank level	0 1 19.0 1	2 28.0 2	3 40.0 3	4 49.0 4 0	5 41.0 5	6 36.0 6	7 26.0 7 0	8 37.0 8	9 30.0 9	10 28.0 10	11 44.0 11	12 31.0 12	13 30.0 13	14 35.0 14	15 35.0 15	16 28.0 16 0
hour pump volume tank level	1 1 0 1 30.0	2 0 2 36.0	3 0 3 48.0	4 1 4 42.0	5 1 5 47.0	6 0 6 48.0	7 0 7 39.0	8 0 8 46.0	9 0 9 44.0	10 0 10 39.0	11 0 11 50.0	12 0 12 40.0	13 0 13 38.0	14 0 14 45.0	15 0 15 41.0	16 0 16 42.0
hour pump volume tank level	2 1 0 1 48.0	2 0 2 44.0	3 1 3 46.0	4 1 4 40.0	5 1 5 46.0	6 1 6 46.0	7 1 7 38.0	8 1 8 45.0	9 0 9 50.0	10 0 10 50.0	11 1 11 55.0	12 1 12 40.0	13 0 13 43.0	14 1 14 42.0	15 0 15 50.0	16 1 16 42.0
hour pump volume tank level	3 1 1 49.0	2 1 2 37.0	3 1 3 39.0	4 1 4 39.0	5 1 5 43.0	6 1 6 48.0	7 0 7 50.0	8 1 8 47.0	9 1 9 49.0	10 1 10 42.0	11 1 11 49.0	12 1 12 39.0	13 1 13 51.0	14 1 14 39.0	15 1 15 47.0	16 0 16 48.0
hour pump volume tank level	4 1 1 1 52.0	2 0 2 46.0	3 0 3 47.0	4 1 4 41.0	5 1 5 42.0	6 1 6 48.0	7 1 7 48.0	8 1 8 40.0	9 1 9 4 8.0	10 1 10 41.0	11 1 11 41.0	12 1 12 39.0	13 1 13 54.0	14 1 14 42.0	15 1 15 41.0	16 1 16 42.0
hour pump volume tank level	5 1 1 48.0	2 1 2 46.0	3 1 3 45.0	4 1 4 37.0	5 0 5 50.0	6 1 6 50.0	7 1 7 49.0	8 0 8 49.0	9 1 9 50.0	10 1 10 49.0	11 1 11 41.0	12 1 12 42.0	13 1 13 52.0	14 0 14 49.0	15 1 15 41.0	16 1 16 42.0
hour pump volume tank level	6 1 1 1 52.0	2 1 2 48.0	3 1 3 47.0	4 0 4 46.0	5 1 5 43.0	6 1 6 46.0	7 1 7 46.0	8 1 8 45.0	9 1 9 48.0	10 1 10 45.0	11 1 11 38.0	12 1 12 43.0	13 1 13 53.0	14 1 14 44.0	15 0 15 50.0	16 1 16 39.0
hour pump volume tank level	7 1 1 1 45.0	2 1 2 46.0	3 1 3 45.0	4 1 4 44.0	5 1 5 42.0	6 1 6 44.0	7 1 7 44.0	8 1 8 42.0	9 1 9 48.0	10 1 10 42.0	11 0 11 45.0	12 0 12 50.0	13 1 13 44.0	14 1 14 44.0	15 1 15 53.0	16 0 16 44.0
hour pump volume tank level	8 1 1 49.0	2 1 2 49.0	3 1 3 48.0	4 1 4 44.0	5 1 5 40.0	6 1 6 38.0	7 1 7 44.0	8 0 8 50.0	9 1 9 50.0	10 1 10 37.0	11 1 11 43.0	12 1 12 48.0	13 1 13 50.0	14 0 14 50.0	15 1 15 53.0	16 1 16 40.0
hour pump volume tank level	9 1 1 1 47.0	2 1 2 43.0	3 1 3 47.0	4 1 4 41.0	5 0 5 47.0	6 1 6 38.0	7 1 7 46.0	8 1 8 53.0	9 1 9 48.0	10 0 10 50.0	11 0 11 46.0	12 1 12 44.0	13 1 13 47.0	14 1 14 48.0	15 1 15 52.0	16 1 16 39.0
hour pump volume tank level	10 1 1 1 45.0	2 1 2 41.0	3 1 3 45.0	4 1 4 42.0	5 1 5 38.0	6 0 6 47.0	7 1 7 44.0	8 1 8 54.0	9 1 9 43.0	10 1 10 47.0	11 1 11 45.0	12 1 12 47.0	13 1 13 47.0	14 1 14 50.0	15 1 15 54.0	16 1 16 41.0

hour pump volume tank level	11 1 1 1 40.0	2 1 2 40.0	3 1 3 47.0	4 1 4 41.0	5 0 5 48.0	6 1 6 47.0	7 0 7 50.0	8 1 8 53.0	9 1 9 42.0	10 1 10 45.0	11 1 11 37.0	12 1 12 45.0	13 1 13 41.0	14 1 14 51.0	15 1 15 52.0	16 1 16 39.0
hour pump volume tank level	12 1 0 1 45.0	2 0 2 48.0	3 1 3 45.0	4 0 4 50.0	5 1 5 49.0	6 1 6 45.0	7 1 7 50.0	8 1 8 49.0	9 1 9 36.0	10 1 10 41.0	11 1 11 43.0	12 1 12 40.0	13 1 13 42.0	14 1 14 52.0	15 1 15 54.0	16 1 16 38.0
hour pump volume tank level	13 1 1 1 40.0	2 1 2 42.0	3 1 3 41.0	4 1 4 49.0	5 1 5 43.0	6 1 6 47.0	7 1 7 48.0	8 1 8 49.0	9 0 9 40.0	10 0 10 50.0	11 0 11 48.0	12 1 12 38.0	13 0 13 49.0	14 1 14 46.0	15 1 15 55.0	16 0 16 45.0
hour pump volume tank level	14 1 0 1 48.0	2 1 2 42.0	3 1 3 37.0	4 1 4 49.0	5 1 5 40.0	6 1 6 39.0	7 1 7 45.0	8 1 8 51.0	9 0 9 48.0	10 1 10 41.0	11 1 11 44.0	12 0 12 47.0	13 1 13 47.0	14 1 14 43.0	15 1 15 49.0	16 1 16 45.0
hour pump volume tank level	15 1 1 1 42.0	2 0 2 49.0	3 0 3 49.0	4 1 4 46.0	5 1 5 43.0	6 0 6 47.0	7 1 7 42.0	8 1 8 53.0	9 1 9 48.0	10 1 10 39.0	11 1 11 42.0	12 1 12 50.0	13 1 13 46.0	14 1 14 41.0	15 1 15 51.0	16 1 16 42.0
hour pump volume tank level	16 1 1 1 40.0	2 1 2 48.0	3 1 3 41.0	4 0 4 47.0	5 1 5 42.0	6 1 6 44.0	7 0 7 50.0	8 1 8 52.0	9 1 9 42.0	10 1 10 41.0	11 1 11 43.0	12 1 12 55.0	13 1 13 45.0	14 1 14 39.0	15 1 15 41.0	16 1 16 41.0
hour pump volume tank level	17 1 1 1 42.0	2 1 2 41.0	3 0 3 49.0	4 1 4 49.0	5 1 5 40.0	6 1 6 46.0	7 1 7 48.0	8 1 8 56.0	9 1 9 43.0	10 0 10 47.0	11 1 11 40.0	12 1 12 48.0	13 1 13 44.0	14 0 14 46.0	15 0 15 49.0	16 0 16 50.0
hour pump volume tank level	18 1 1 41.0	2 1 2 41.0	3 1 3 42.0	4 1 4 44.0	5 1 5 39.0	6 1 6 42.0	7 1 7 43.0	8 1 8 49.0	9 0 9 50.0	10 1 10 46.0	11 1 11 41.0	12 1 12 42.0	13 1 13 41.0	14 1 14 45.0	15 1 15 45.0	16 1 16 47.0
hour pump volume tank level	19 1 1 1 44.0	2 1 2 42.0	3 1 3 40.0	4 0 4 50.0	5 0 5 48.0	6 1 6 39.0	7 1 7 47.0	8 1 8 50.0	9 1 9 45.0	10 1 10 41.0	11 0 11 50.0	12 1 12 40.0	13 0 13 47.0	14 1 14 50.0	15 1 15 48.0	16 1 16 44.0
hour pump volume tank level	20 1 1 1 42.0	2 1 2 43.0	3 0 3 49.0	4 1 4 49.0	5 1 5 45.0	6 0 6 48.0	7 1 7 47.0	8 1 8 48.0	9 1 9 41.0	10 1 10 37.0	11 1 11 47.0	12 0 12 48.0	13 1 13 46.0	14 1 14 55.0	15 1 15 47.0	16 1 16 42.0
hour pump volume tank level	21 1 0 1 49.0	2 1 2 41.0	3 1 3 47.0	4 1 4 47.0	5 1 5 46.0	6 1 6 47.0	7 1 7 50.0	8 1 8 46.0	9 1 9 42.0	10 0 10 46.0	11 1 11 44.0	12 1 12 47.0	13 1 13 47.0	14 1 14 53.0	15 1 15 41.0	16 1 16 44.0

hour pump volume tank level	22 1 1 1 44.0	2 0 2 48.0	3 1 3 50.0	4 1 4 44.0	5 1 5 50.0	6 1 6 41.0	7 1 7 47.0	8 1 8 46.0	9 1 9 51.0	10 1 10 48.0	11 0 11 50.0	12 1 12 47.0	13 1 13 41.0	14 1 14 48.0	15 0 15 46.0	16 1 16 48.0
hour pump volume tank level	23 1 1 1 42.0	2 1 2 49.0	3 1 3 48.0	4 0 4 50.0	5 1 5 53.0	6 0 6 50.0	7 1 7 42.0	8 1 8 44.0	9 1 9 50.0	10 1 10 51.0	11 1 11 46.0	12 1 12 46.0	13 0 13 49.0	14 1 14 43.0	15 1 15 45.0	16 1 16 44.0
hour pump volume tank level	24 1 1 1 42.0	2 1 2 52.0	3 1 3 44.0	4 1 4 50.0	5 1 5 50.0	6 1 6 43.0	7 0 7 49.0	8 1 8 40.0	9 1 9 48.0	10 1 10 44.0	11 1 11 42.0	12 1 12 45.0	13 1 13 49.0	14 1 14 43.0	15 1 15 48.0	16 1 16 40.0
hour pump volume tank level	25 1 1 1 44.0	2 1 2 47.0	3 1 3 45.0	4 1 4 43.0	5 1 5 47.0	6 1 6 42.0	7 1 7 44.0	8 1 8 38.0	9 1 9 42.0	10 1 10 41.0	11 1 11 39.0	12 1 12 50.0	13 1 13 46.0	14 1 14 42.0	15 1 15 45.0	16 1 16 41.0
hour pump volume tank level	26 1 1 1 43.0	2 1 2 48.0	3 1 3 42.0	4 1 4 39.0	5 1 5 43.0	6 1 6 40.0	7 1 7 42.0	8 0 8 44.0	9 0 9 46.0	10 0 10 47.0	11 0 11 45.0	12 1 12 49.0	13 1 13 45.0	14 1 14 40.0	15 1 15 42.0	16 0 16 49.0
hour pump volume tank level	27 1 1 1 48.0	2 1 2 46.0	3 1 3 39.0	4 1 4 39.0	5 1 5 41.0	6 0 6 46.0	7 1 7 41.0	8 1 8 45.0	9 1 9 44.0	10 1 10 48.0	11 1 11 40.0	12 1 12 45.0	13 0 13 50.0	14 0 14 48.0	15 1 15 45.0	16 1 16 43.0
hour pump volume tank level	28 1 1 1 44.0	2 1 2 43.0	3 1 3 41.0	4 0 4 48.0	5 0 5 45.0	6 1 6 40.0	7 0 7 50.0	8 1 8 43.0	9 1 9 40.0	10 1 10 45.0	11 1 11 37.0	12 1 12 44.0	13 1 13 51.0	14 1 14 51.0	15 1 15 37.0	16 1 16 46.0
hour pump volume tank level	29 1 1 1 42.0	2 1 2 43.0	3 1 3 40.0	4 1 4 46.0	5 1 5 46.0	6 1 6 38.0	7 1 7 51.0	8 1 8 43.0	9 1 9 38.0	10 0 10 49.0	11 0 11 48.0	12 1 12 38.0	13 1 13 46.0	14 1 14 51.0	15 0 15 42.0	16 1 16 41.0
hour pump volume tank level	30 1 0 1 50.0	2 1 2 44.0	3 1 3 46.0	4 1 4 43.0	5 1 5 43.0	6 0 6 50.0	7 1 7 51.0	8 1 8 46.0	9 0 9 47.0	10 1 10 42.0	11 1 11 45.0	12 1 12 43.0	13 1 13 41.0	14 1 14 48.0	15 1 15 43.0	16 1 16 43.0
hour pump volume tank level	31 1 1 46.0	2 1 2 45.0	3 1 3 47.0	4 1 4 45.0	5 0 5 49.0	6 1 6 51.0	7 1 7 51.0	8 1 8 44.0	9 1 9 42.0	10 0 10 49.0	11 0 11 46.0	12 0 12 46.0	13 1 13 42.0	14 1 14 46.0	15 1 15 45.0	16 1 16 39.0
hour pump volume tank level	32 1 1 1 42.0	2 1 2 45.0	3 1 3 41.0	4 1 4 47.0	5 1 5 51.0	6 1 6 46.0	7 1 7 49.0	8 1 8 43.0	9 1 9 40.0	10 1 10 46.0	11 1 11 45.0	12 1 12 49.0	13 1 13 41.0	14 1 14 38.0	15 1 15 48.0	16 1 16 42.0

hour pump volume tank level	33 1 1 1 39.0	2 1 2 47.0	3 1 3 39.0	4 1 4 46.0	5 1 5 49.0	6 1 6 45.0	7 1 7 46.0	8 1 8 40.0	9 0 9 47.0	10 1 10 48.0	11 1 11 41.0	12 1 12 47.0	13 0 13 49.0	14 0 14 47.0	15 1 15 38.0	16 1 16 38.0
hour pump volume tank level	34 1 0 1 46.0	2 1 2 44.0	3 0 3 49.0	4 1 4 42.0	5 1 5 44.0	6 0 6 49.0	7 1 7 51.0	8 0 8 45.0	9 1 9 47.0	10 1 10 49.0	11 0 11 50.0	12 1 12 43.0	13 1 13 43.0	14 1 14 50.0	15 0 15 46.0	16 0 16 46.0
hour pump volume tank level	35 1 1 1 41.0	2 1 2 41.0	3 1 3 43.0	4 0 4 48.0	5 1 5 45.0	6 1 6 44.0	7 1 7 46.0	8 1 8 44.0	9 1 9 50.0	10 1 10 43.0	11 1 11 53.0	12 1 12 40.0	13 1 13 40.0	14 1 14 54.0	15 1 15 40.0	16 1 16 47.0
hour pump volume tank level	36 1 0 1 46.0	2 1 2 40.0	3 1 3 50.0	4 1 4 45.0	5 1 5 41.0	6 1 6 43.0	7 1 7 39.0	8 1 8 42.0	9 1 9 51.0	10 0 10 49.0	11 1 11 51.0	12 1 12 37.0	13 1 13 41.0	14 1 14 51.0	15 1 15 40.0	16 1 16 39.0
hour pump volume tank level	37 1 1 50.0	2 1 2 41.0	3 1 3 49.0	4 1 4 48.0	5 1 5 41.0	6 1 6 43.0	7 0 7 48.0	8 0 8 48.0	9 1 9 48.0	10 1 10 54.0	11 1 11 46.0	12 0 12 43.0	13 0 13 47.0	14 1 14 48.0	15 0 15 50.0	16 0 16 48.0
hour pump volume tank level	38 1 1 52.0	2 1 2 37.0	3 1 3 46.0	4 1 4 50.0	5 1 5 39.0	6 0 6 49.0	7 1 7 40.0	8 1 8 51.0	9 1 9 51.0	10 1 10 55.0	11 1 11 44.0	12 0 12 47.0	13 1 13 44.0	14 1 14 50.0	15 1 15 51.0	16 1 16 42.0
hour pump volume tank level	39 1 1 47.0	2 1 2 44.0	3 1 3 46.0	4 1 4 50.0	5 0 5 48.0	6 1 6 49.0	7 0 7 46.0	8 1 8 50.0	9 1 9 41.0	10 1 10 55.0	11 1 11 41.0	12 1 12 42.0	13 1 13 42.0	14 1 14 50.0	15 1 15 52.0	16 0 16 48.0
hour pump volume tank level	40 1 1 1 41.0	2 1 2 42.0	3 1 3 41.0	4 1 4 50.0	5 1 5 49.0	6 1 6 54.0	7 1 7 45.0	8 1 8 46.0	9 1 9 40.0	10 1 10 49.0	11 0 11 45.0	12 0 12 49.0	13 0 13 50.0	14 1 14 49.0	15 1 15 49.0	16 1 16 49.0
hour pump volume tank level	41 1 0 1 49.0	2 1 2 49.0	3 1 3 38.0	4 1 4 53.0	5 1 5 40.0	6 1 6 52.0	7 1 7 40.0	8 1 8 42.0	9 0 9 48.0	10 1 10 53.0	11 0 11 49.0	12 1 12 50.0	13 1 13 50.0	14 1 14 47.0	15 1 15 47.0	16 1 16 45.0
hour pump volume tank level	42 1 1 46.0	2 1 2 47.0	3 0 3 48.0	4 1 4 52.0	5 1 5 40.0	6 1 6 51.0	7 1 7 42.0	8 1 8 47.0	9 1 9 54.0	10 1 10 50.0	11 1 11 47.0	12 1 12 46.0	13 1 13 38.0	14 1 14 38.0	15 1 15 47.0	16 1 16 46.0
hour pump volume tank level	43 1 1 1 44.0	2 1 2 40.0	3 1 3 42.0	4 1 4 50.0	5 0 5 50.0	6 1 6 47.0	7 1 7 42.0	8 1 8 38.0	9 1 9 45.0	10 1 10 48.0	11 1 11 49.0	12 1 12 55.0	13 1 13 44.0	14 0 14 45.0	15 0 15 49.0	16 1 16 45.0

hour pump volume tank level	44 1 1 1 44.0	2 1 2 43.0	3 0 3 50.0	4 1 4 48.0	5 1 5 50.0	6 1 6 40.0	7 1 7 39.0	8 0 8 46.0	9 1 9 46.0	10 1 10 44.0	11 1 11 50.0	12 1 12 49.0	13 1 13 43.0	14 1 14 45.0	15 1 15 45.0	16 1 16 43.0
hour pump volume tank level	45 1 0 1 50.0	2 0 2 49.0	3 1 3 47.0	4 1 4 48.0	5 1 5 44.0	6 0 6 49.0	7 1 7 35.0	8 1 8 44.0	9 1 9 44.0	10 1 10 42.0	11 1 11 48.0	12 1 12 45.0	13 1 13 37.0	14 1 14 40.0	15 1 15 40.0	16 1 16 42.0
hour pump volume tank level	46 1 1 1 49.0	2 1 2 52.0	3 1 3 44.0	4 1 4 55.0	5 1 5 39.0	6 1 6 45.0	7 0 7 45.0	8 1 8 45.0	9 1 9 42.0	10 0 10 50.0	11 1 11 49.0	12 1 12 49.0	13 0 13 45.0	14 0 14 48.0	15 1 15 42.0	16 1 16 41.0
hour pump volume tank level	47 1 1 1 46.0	2 1 2 54.0	3 1 3 39.0	4 1 4 51.0	5 1 5 41.0	6 1 6 38.0	7 1 7 43.0	8 1 8 47.0	9 1 9 41.0	10 1 10 48.0	11 1 11 45.0	12 1 12 43.0	13 1 13 41.0	14 1 14 48.0	15 0 15 50.0	16 1 16 46.0
hour pump volume tank level	48 1 1 1 40.0	2 1 2 52.0	3 1 3 40.0	4 1 4 45.0	5 1 5 37.0	6 0 6 48.0	7 1 7 40.0	8 1 8 45.0	9 0 9 50.0	10 1 10 54.0	11 1 11 40.0	12 1 12 40.0	13 1 13 40.0	14 1 14 48.0	15 1 15 49.0	16 1 16 46.0