

SMART GRIDS

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GOAL

- DESIGN A MULTIAGENT SYSTEM IN WHICH A SET OF POWER PRODUCERS AND CONSUMERS IN A POWER GRID COMMUNICATE AND ACT TO MAXIMIZE EFFICIENCY AND MINIMIZE BLACKOUTS

ENVIRONMENT

- N AGENT NODES ON A GRAPH – REPRESENTING A POWER GRID
- EACH AGENT IS A POWER PRODUCER, A POWER CONSUMER, OR BOTH (REPRESENTING HOMES WITH SMALL GENERATORS OR SOLAR PANELS)
- BETWEEN NODES YOU HAVE POWER LINES WHICH ARE SLIGHTLY INEFFICIENT
 - INEFFICIENCY PROPORTIONAL TO DISTANCE

PRODUCERS

- 3 TYPES OF PRODUCERS
 - PERIODIC PRODUCERS
 - E.G. SOLAR PANELS
 - PRODUCE POWER ONLY DURING THE DAY
 - SPIN-UP PRODUCERS
 - PRODUCE A SPECIFIC AMOUNT OF ENERGY AFTER A LONG “SPIN-UP” TIME
 - QUICK PRODUCERS
 - PRODUCE A SPECIFIC AMOUNT OF ENERGY AFTER A MUCH SHORTER “SPIN-UP” TIME
 - SLIGHTLY LESS COST EFFICIENT THAN SPIN-UP, BUT MORE REACTIVE

CONSUMERS

- DAILY INCOME I
 - UNUSED INCOME DOES NOT CARRY OVER BETWEEN DAYS (ASSUMED TO BE SPENT ON LUXURIES)
- CONSUMPTION $C(t) = S(t) + R$
 - BASED ON ACTUAL HOUSEHOLD ENERGY CONSUMPTION, SLIGHTLY SIMPLIFIED
 - $P(t)$ SINEWAVE PEAKING IN THE EVENING (WHEN MOST PEOPLE ARE HOME AND REQUIRING THE MOST TEMPERATURE ADJUSTMENT)
 - R IS A NORMAL RANDOM VARIABLE TO ADD ELEMENT OF UNPREDICTABILITY
- A LIST OF ALL KNOWN PRODUCERS

CONSUMER SIDE NEGOTIATIONS

- AT EACH TIME STEP (24 IN A DAY) CONSUMERS WILL ATTEMPT TO PURCHASE ENOUGH POWER TO SUPPLY THEIR $C(T)$ FROM IT'S KNOWN ACTIVE PRODUCERS
- CONSUMERS WILL BROADCAST THEIR IDENTITY AND THE MINIMUM PRICE NECESSARY TO SATISFY THEIR POWER NEEDS
- IF A PRODUCER CAN SATISFY THEIR NEEDS FOR A LOWER PRICE, THEY WILL RESPOND WITH IT'S IDENTITY
- BOTH PRODUCERS AND CONSUMERS NEED TO TAKE INTO CONSIDERATION INEFFICIENCIES IN POWER TRANSFER DUE TO DISTANCE
- A CONSUMER THAT IS OUT OF MONEY OR OTHERWISE UNABLE TO SATISFY IT'S POWER NEEDS IS CONSIDERED BLACKED OUT

PRODUCER SIDE CONSIDERATIONS

- PRODUCERS WANT TO MAXIMIZE THEIR PROFITS
 - WANT TO SELL POWER FOR MORE THAN IT COST TO PRODUCE
 - BUT LOW ENOUGH THAT CONSUMERS CAN AFFORD IT
 - THERE WILL BE COMPETITION BETWEEN PRODUCERS
- PERIODIC PRODUCERS
 - LOW COST BUT NOT ALWAYS AVAILABLE
- SPIN-UP PRODUCERS
 - EXTREMELY LOW MARGINAL COST IF THEY CAN RUN FOR A LONG TIME
 - SPIN-UP COSTS A FIXED AMOUNT AND THIS COST WILL BE DISTRIBUTED OVER TIME IT EXPECTS TO RUN
- QUICK PRODUCERS
 - HIGHER COST THAT SPIN-UP BUT ABLE TO BE MUCH MORE REACTIVE

DECISION TO “SPIN-UP”

- SPIN UP PRODUCERS WILL RECORD PRICES RECEIVED FROM CONSUMERS AT EACH TIME STEP
- IF IT FINDS A LONG ENOUGH PERIOD OF HIGH POWER PRICES, IT WILL BEGIN SPIN-UP THE NEXT DAY FOR THAT AMOUNT OF TIME
- QUICK PRODUCERS SIMPLY SPIN UP IF THEIR COST OF PRODUCTION IS LOWER THAN THE CURRENT TIME STEP'S MINIMUM PRICE AND SPIN DOWN IN THE PRICE BECOMES TO LOW

DESIRED EMERGENT BEHAVIOR

- PRODUCERS OPERATING AT MAXIMUM EFFICIENCY
- CONSUMERS PAYING AS LITTLE AS POSSIBLE
- NO BLACKOUTS

VARIABLES

- CONSUMERS
 - I – DAILY INCOME
 - $P(T)$ – PARAMETERS FOR DAILY PREDICTABLE CONSUMPTION
 - R – DISTRIBUTION OF RANDOM ELEMENT OF CONSUMPTION
- PRODUCERS
 - SPIN-UP AND MARGINAL COSTS
- POWERLINES
 - DEGREE OF INEFFICIENCY

HYPOTHESES

- EFFICIENCY OF A NETWORK WILL MONOTICALLY INCREASE OVERTIME AS CONSUMER BECOME BETTER CONSUMERS BECOME BETTER CONNECTED WITH PRODUCERS OF HIGHER EFFICIENCY, EVEN UNDER CONDITIONS OF SEMI-RANDOM CONSUMPTION (HIGH VARIANCE IN R)
- IF CONSUMERS POWER DEMAND IS CHAOTIC THEN CONSUMERS WILL RELY MORE ON QUICK PRODUCERS WHICH ARE ABLE TO RESPOND MORE EFFICIENTLY TO CHANGING DEMAND
- IF TOTAL INCOME IS LOWER THAN THE COST OF PROVIDING ALL POWER WITH QUICK PRODUCERS, THE SYSTEM WILL EXPERIENCE FREQUENT BLACKOUTS EVEN THOUGH THERE ARE OTHER POWER SOURCES THAT ARE CHEAPER BUT LESS RELIABLE
- OTHERWISE IDENTICAL CITIES WITH DIFFERENT STANDARD DEVIATIONS FOR THE DISTRIBUTION OF INEFFICIENCIES IN POWER LINES WILL NOT HAVE SIGNIFICANT DIFFERENCES IN OVERALL EFFICIENCY