Scheduling Electric Power Restoration

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Abstract:

After Tropical Storm Irene and the Halloween snowstorm, everybody understands the need for rapid restoration of electric power. Optimal job scheduling is an NP-complete problem, which means, in ordinary English, that the only known solution is a full enumeration of all possible schedules.

As near as we can tell, CL&P uses either a "First Come, First Served" (FCFS) policy or an "Outside In" policy for scheduling their crews. FCFS means that the jobs are scheduled in the order that they're called in, and "Outside In" means that crews are sent to the borders of affected areas and they then work their way in to the center of an affected area. This last method is equivalent to what's called the "Nearest Neighbor" algorithm, which is equivalent to "Shortest Travel Time First" scheduling.

The authors wondered whether a scheduling algorithm known as "Longest Remaining Job First" (LRJF) might produce better results. LRJF is a "near-optimal" algorithm, apparently discovered by Prof. Todd in the early 90s, that when used for scheduling jobs for parallel processing, results in faster job completion times.

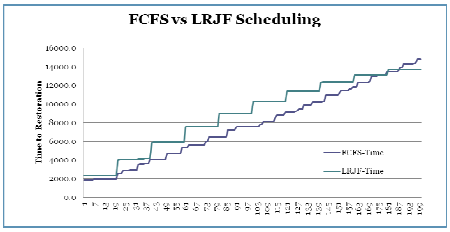
Description:

When calculating the "length" of a job, LRJF can use "time-to-repair" (TTR) or it can include crew travel time from their current location to the next job. The first option will be identified as "LRJF:TTR" and the second as "LRJF:TTR+Trv."

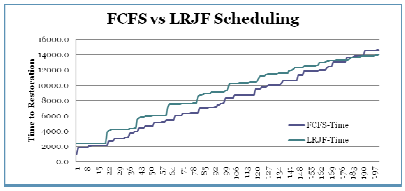
Other scheduling criteria included the goal expressed by the then-COO of CL&P to restore "the most people in the shortest time." To meet this requirement, we thought that scheduling the ratio of affected population to TTR by LRJF might meet his objective. We also considered scheduling the product of affected population and TTR, since the ratio method would push large values of TTR to the end of the schedule. These two methods are identified as "LRJF:Ratio" and "LRJF:Product." Finally, we considered simply scheduling the largest affected area first, without regard for the TTR. This method was identified as "LRJF:Popn."

We wrote a simulation using Excel to compare the complete restoration times for all of the aforementioned methods. Here is a list of the scheduling methods that were investigated and their advantages and disadvantages.

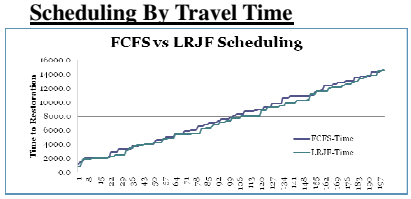
Scheduling By Time to Repair + Travel Time



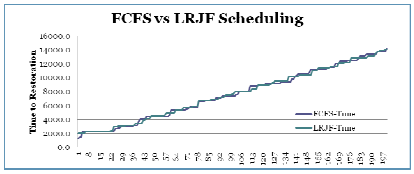
Scheduling By Time To Repair



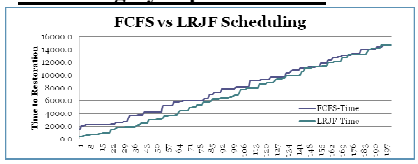
Scheduling By Travel Time



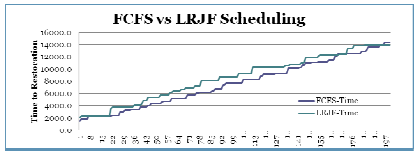
Scheduling By Population Number



Scheduling By Population/Time



Scheduling By Population*Time



Methods: FCFS and "Outside-In"

Advantages:
These methods are easy to implement. They are "information cheap," meaning that little communication between crews, or between crews and headquarters, is required.
Disadvantages:
They both result in relatively long restoration times.

Method: LRJF:TTR

Advantages:
This method results in demonstrably faster restoration times, especially when there is large variation in TTR values.
Disadvantages:
This algorithm can't be used until many events are called in and repair times estimated. Fortunately for the method, most events occur before crews are sent into the field. Unfortunately for the method, reasonably reliable estimates of TTR are required and gathering this information requires "boots on the ground" throughout the affected areas. Further, the people doing the estimating must be qualified and experienced linemen. Perhaps most importantly, if there is little variation in TTR and if there are many more events than crews, very little is gained by elaborate scheduling

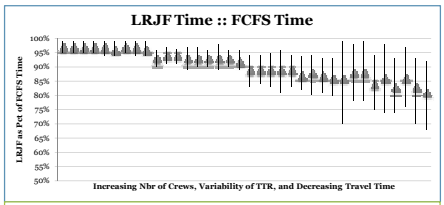
Method: LRJF:TTR+Trv

Advantages:
This method more accurately determines which jobs are in fact the longest and produces the quickest restoration of power.
Disadvantages:
There is the additional information requirement that knowledge of blocked access routes (due to downed trees) be known, but already having people present to estimate TTR adds little to the information requirements. Unfortunately, the same caveat about variability of TTR and available crews applies to this method, too.

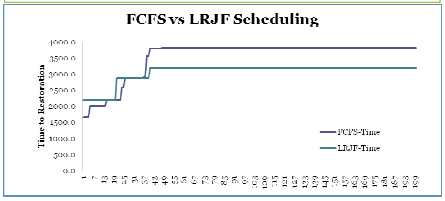
Method: All the others

Advantages:
None. They are at least as bad as FCFS or Outside-In.
Disadvantages:
Not only are they inferior, their information requirements are the worst.

Jobs/Crew	TTR	Trv	Best	Worst	Avg				
20	5	20	95	99	97	95%	99%	97%	
20	5	10	95	99	97	95%	99%	97%	
20	5	2	95	99	97	95%	99%	97%	
20	10	20	95	99	97	95%	99%	97%	
20	10	10	94	99	97	94%	99%	97%	
20	10	2	94	99	96	94%	99%	96%	
20	20	20	95	99	97	95%	99%	97%	
20	20	10	94	99	97	94%	99%	97%	
20	20	2	94	99	96	94%	99%	96%	
10	5	20	90	96	93	90%	96%	93%	
10	5	10	91	97	94	91%	97%	94%	
10	5	2	91	96	94	91%	96%	94%	
10	10	20	89	97	93	89%	97%	93%	
10	10	10	90	97	93	90%	97%	93%	
10	10	2	90	96	93	90%	96%	93%	
10	20	20	89	98	93	89%	98%	93%	
10	20	10	90	96	93	90%	96%	93%	
10	20	2	89	96	92	89%	96%	92%	
5	5	20	83	94	89	83%	94%	89%	
5	5	10	84	94	89	84%	94%	89%	
5	5	2	83	95	89	83%	95%	89%	
5	10	20	81	96	89	81%	96%	89%	
5	10	10	83	94	89	83%	94%	89%	
5	10	2	82	94	87	82%	94%	87%	
5	20	20	80	94	88	80%	94%	88%	
5	20	10	81	93	87	81%	93%	87%	
5	20	2	80	93	86	80%	93%	86%	
2.5	5	20	70	99	86	70%	99%	86%	
2.5	5	10	78	98	88	78%	98%	88%	
2.5	5	2	78	99	88	78%	99%	88%	
2.5	10	20	75	94	84	75%	94%	84%	
2.5	10	10	74	98	86	74%	98%	86%	
2.5	10	2	74	93	83	74%	93%	83%	
2.5	20	20	76	97	86	76%	97%	86%	
2.5	20	10	70	93	83	70%	93%	83%	
2.5	20	2	68	92	81	68%	92%	81%	



This graph below illustrates the results when Time To Repair is highly variable, number of crews with respect to jobs is high and the Travel Time is minimized.



Summary:

- If there are many crews available,
- AND if there is a lot of variability in TTR or TTR+Trv
- AND if communication channels exist
- ➢ THEN scheduling by LRJF:TTR+Trv can reduce restoration time by as much as 30% to 35%.