Load Management System Optimization For Northern Virginia Electric Cooperative (NOVEC)

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OR-680/SYST-798 Capstone Project Proposal

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1 INTRODUCTION

Northern Virginia Electric Cooperative (NOVEC) is headquartered in Manassas, Virginia and is an electricity reseller serving residential, commercial, and industrial customers. NOVEC owns an electricity distribution network but does not currently own any electric generation . Consequently, NOVEC must purchase power from the wholesale power market which must be delivered through the PJM Interconnection* (PJM). PJM is a regional transmission organization (RTO) that coordinates the movement of wholesale electricity in all or parts of 13 states, including Virginia and the District of Columbia.

2 OVERVIEW

This document is a proposal by the Electric Management Group (EMG) to develop technology that will allow NOVEC to better manage the peak demand that NOVEC can only satisfy by the purchase of energy at premium spot market prices. Section 3 provides background information on how NOVEC purchases power for resale and NOVEC's Load Management Program (LMP). Section 4 describes the problem to be solved by the project. Section 5 identifies the major project stakeholders and their representatives. Section 6 describes the project scope. Section 7 identifies the project-wide assumptions made to facilitate the research. Section 8 identifies high-level requirements for the work to be performed as well as key functional and performance requirements for the technical solution. Section 9 summarizes the technical solution concept and the technical approach the project will use to realize the solution concept. Section 10 identifies the technical solution deliverables that will be produced by the project effort. Section 11 provides a summary work breakdown structure (WBS). Section 12 presents a summary schedule that corresponds with the WBS.

3 BACKGROUND

3.1 NOVEC ELECTRICITY PURCHASE OVERVIEW

Generating capacity is the ability to provide electrical energy at certain rate, i.e., power. Capacity must be sized and acquired for the worst case demand which, for NOVEC, occurs during the summer period that spans June 1 through September 30 of each year. PJM assigns to NOVEC its annual peak capacity requirement that is determined using a complex formula based predominately on NOVEC's previous summer peak demand and NOVEC's forecasted peak

* http://www.pjm.com/about-pjm.aspx

consumption for the upcoming summer period. It benefits NOVEC customers when NOVEC is able to control its customer peak hour usage and thus minimize its annual summer peak capacity requirements and energy purchases. NOVEC works hard to forecast and control its actual hourly peak demand that will occur during the summer period and uses this estimate to purchase capacity in advance. An advance purchase ahead of the summer is necessary because NOVEC must be sure that its meets its PJM assigned capacity obligation and has sufficient capacity to serve its customers' energy needs during summer peak hours. NOVEC must acquire and have available a level capacity equal to its peak hour demand for the entire summer period (June 1 through September 30) even if this peak demand is used only for single hour during this summer period. Accordingly it is to NOVEC's benefit to minimize customer usage during these few hours of high consumption in order to minimize its summer period capacity requirement and energy purchases. Effective use of a load management program designed to turn off selected customer loads during peak consumption periods is the current method employed by NOVEC to reduce its peak period consumption.

Energy is purchased using two methods that reflect both the average energy consumption (base load) and the deviations from the average (intermediate and peak loads). Base load consumption is satisfied by energy purchased using negotiated, firm price, bilateral contracts. These contracts are purchased one month to three years in advance of consumption and make up a majority of NOVEC's energy purchases and sales.

Peak load consumption is satisfied by spot market energy purchases made either on the same day, or up to one day before, the energy is consumed. The quantity of these purchases is determined by the number of kilowatt-hours used during peak electricity-use times. Spot market prices are volatile and high, particularly during periods of high energy consumption, due to the competition that occurs between utilities seeking purchases on the PJM marketplace. The PJM marketplace updates and posts its market energy prices every hour. Accordingly a second benefit of the effective use of a load management program is to reduce customer consumption of energy during periods of time when the price wholesale commodity price of electric energy is at the highest level.

3.2 LOAD MANAGEMENT PROGRAM

NOVEC has instituted the voluntary Load Management Program (LMP) for its residential customers as a way to reduce peak power demand and thus reduce the purchase of expensive spot market purchases of the energy to satisfy the peak power demand. Customers in this program allow NOVEC to install remote controlled switches on their hot water heaters and/or air conditioning compressor units. Customers then agree to allow NOVEC to switch off these appliances for a fraction of an hour during peak energy use times.

Participation in the program gives NOVEC the opportunity to better control the residential demand for peak power and potentially reduce NOVEC's energy purchase costs by a few million dollars each year.

4 PROBLEM STATEMENT

Currently, the Load Management Program has a Load Management System (LMS) comprising approximately 43,000 remote control switches installed on residential hot water and/or air conditioning units within NOVEC's service region. The 43,000 switches are controlled in blocks of approximately 5,000 units each such that all the switches within a block are commanded to switch on or off in unison at any time.

NOVEC would like to determine how the operation of LMS can be optimized to maximize the benefit of reducing peak electricity demand. In particular, NOVEC has interest in the daily on/off scheduling of the load management switches as well as discovering if the current switch block size of 5,000 units is optimal. A successful optimization approach is one that simultaneously reduces peak electricity demand, reduces peak energy consumption but minimizes reductions in overall energy sales, and maintains customer satisfaction in the provided electricity service.

NOVEC has indicated the operation of the LMS is guided by an associated load management policy. As such, NOVEC seeks a recommended load management policy or set of policies that:

- Accommodate multiple peak load scenarios driven by seasonal and time of day influences
- Provide potential cost savings for NOVEC customers.

5 STAKEHOLDERS

As the project sponsor, NOVEC is the primary stakeholder in the results of the project. A successful outcome of the project faces real potential of being adopted by NOVEC to control peak demand energy consumption by NOVEC's residential customers. NOVEC has two representatives, Angie Thomas and Bob Bisson, who will be working with the Electric Management Group during the course of the project.

6 PROJECT SCOPE

The scope of this project is the development and demonstration of an algorithm and associated load management policy that optimizes the operation of the LMS to reduce peak energy demand while minimizing the reduction of overall energy sales and customer satisfaction. Demonstration of the effectiveness of the algorithm and associated policy will be accomplished by computer simulation of an LMS optimization prototype driven by historical data sets of power demand and weather data provided by NOVEC. The project will provide a technical report that describes the research approach, the experiment design, obtained results, and conclusions. Furthermore, the developed simulations and load management policies will be made available to NOVEC.

7 ASSUMPTIONS

The project will perform the research using the following assumptions:

a) The research will focus on the summer months as peak demand is highest and most volatile during these months. Furthermore, limiting the focus to the summer months will reduce the size of the data sets that NOVEC will need to provide.

b) The temperatures reported by Dulles Airport will stand as the temperatures for the NOVEC service region if it is not possible to obtain hourly temperature data on a municipality-scale basis

c) Customer satisfaction is primarily perceived personal comfort within the home for a given outside temperature. Therefore the project team will use a heat index formulation[*] as a proxy measure for customer satisfaction with NOVEC's Load Management Program. The heat index attempts to model human-perceived comfort as a function of temperature and humidity.

8 PRELIMINARY REQUIREMENTS

The following high-level project and technical requirements were determined by the Electric Management Group (EMG) through background research and preliminary conversations with the stakeholders.

8.1 PROJECT REQUIREMENTS

a) The EMG shall create an optimization algorithm for the NOVEC Load Management System (LMS).

b) The EMG shall develop one or more load management policies that maximize the effectiveness of the LMS optimization algorithm.

c) The EMG shall investigate how different switch block sizes affect the ability to optimize the operation of the LMS.

d) The EMG shall produce informal progress reports for the sponsor to show steps made in the production of the model.

[*] Steadman, R. G., 1979: The Assessment of Sultriness. Part I: A Temperature-Humidity Index Based on Human Physiology and Clothing Science. *Journal of Applied Meteorology*, 18, 861–873.

e) The EMG shall produce a final report to be presented to the stakeholders by May 11, 2012.

f) The EMG shall produce a website containing the final report and presentation.

8.2 LOAD MANAGEMENT SYSTEM OPTIMIZER (LMSO) TECHNICAL REQUIREMENTS

a) The LMSO shall provide managed peak demand estimates every 15 minutes to support spot market power purchase planning decisions that are made on an hourly basis.

b) The LMSO shall provide LMS control guidance every 15 minutes to coincide with NOVEC's demand load measurement frequency.

c) The LMSO shall use temperature forecasts and measurements for NOVEC's residential customer locales to optimize load management system operation.

d) The LMSO shall use real-time monitoring of actual power demand to confirm optimized LMS operations reduce peak demand by the percent reduction objective set by NOVEC.

8.3 LOAD MANAGEMENT SYSTEM POLICY (LMSP) TECHNICAL REQUIREMENTS

a) The LMSP shall ensure no more than 5% of participating residences experience diminished satisfaction of NOVEC's electrical service due to lack of air conditioning caused by the operation of the LMS.

b) The LMSP shall ensure no more than 5% of participating residences experience diminished satisfaction of NOVEC's electrical service due to lack of hot water caused by the operation of the LMS.

c) The LMSP shall provide flexibility in the operation of the LMS to achieve peak demand percent reduction objectives.

d) The LMSP shall allow the LMSO to achieve peak demand reductions within 20% of the desired percent reduction objective.

9 SOLUTION DEVELOPMENT

This section discusses the technical approach to develop the solution to the questions of optimized LMS operation and the associated load management policy. Through initial discussions with NOVEC, the Electric Management Group has already determined a conceptual process that appears promising in its ability to optimize the operation of the NOVEC LMS. This conceptual process will be discussed to provide a context for the description of the technical approach that will result in a realization of the process.

9.1 CONCEPTUAL LOAD MANAGEMENT OPTIMIZATION PROCESS

A summary-level portrayal of the optimization process for load management system operation is shown in Figure 1 on page 8. As shown in the figure, the process begins with developing an estimate for the unmanaged peak demand using temperature forecasts for a 24-hour period. This estimate assumes that all residences in the NOVEC service region can draw electrical energy at will to calculate a demand versus time profile.

The unmanaged peak demand estimate is then used in conjunction with an independently set peak demand reduction objective to select a load management policy to follow. The selected load management policy is then used to determine the estimated managed peak demand. This estimate uses the population of residences that participate in NOVEC's Load Management Program to compute the expected peak demand that results from the enforcement of the selected load management policy.

The estimated managed peak demand is compared to the estimated unmanaged peak demand to see if the desired peak demand reduction objective has been reached. If the objective is not reached, then it can be seen in Figure 1 that an inner return loop causes the process to select a different load management policy. Otherwise, if the reduction objective is met, then the process forwards the load management policy on to the LMS controller to implement the load management policy for real. Simultaneously, the estimated managed peak demand is provided as input to the system used to determine spot power purchases.

The optimization process is intended continuously execute as evidenced by the outer loop that shows the process flow returning to the beginning stage of estimating the unmanaged peak demand. The frequency of this repeating execution depends on the needs of NOVEC systems that utilize the managed peak demand estimate and the selected load management policy.

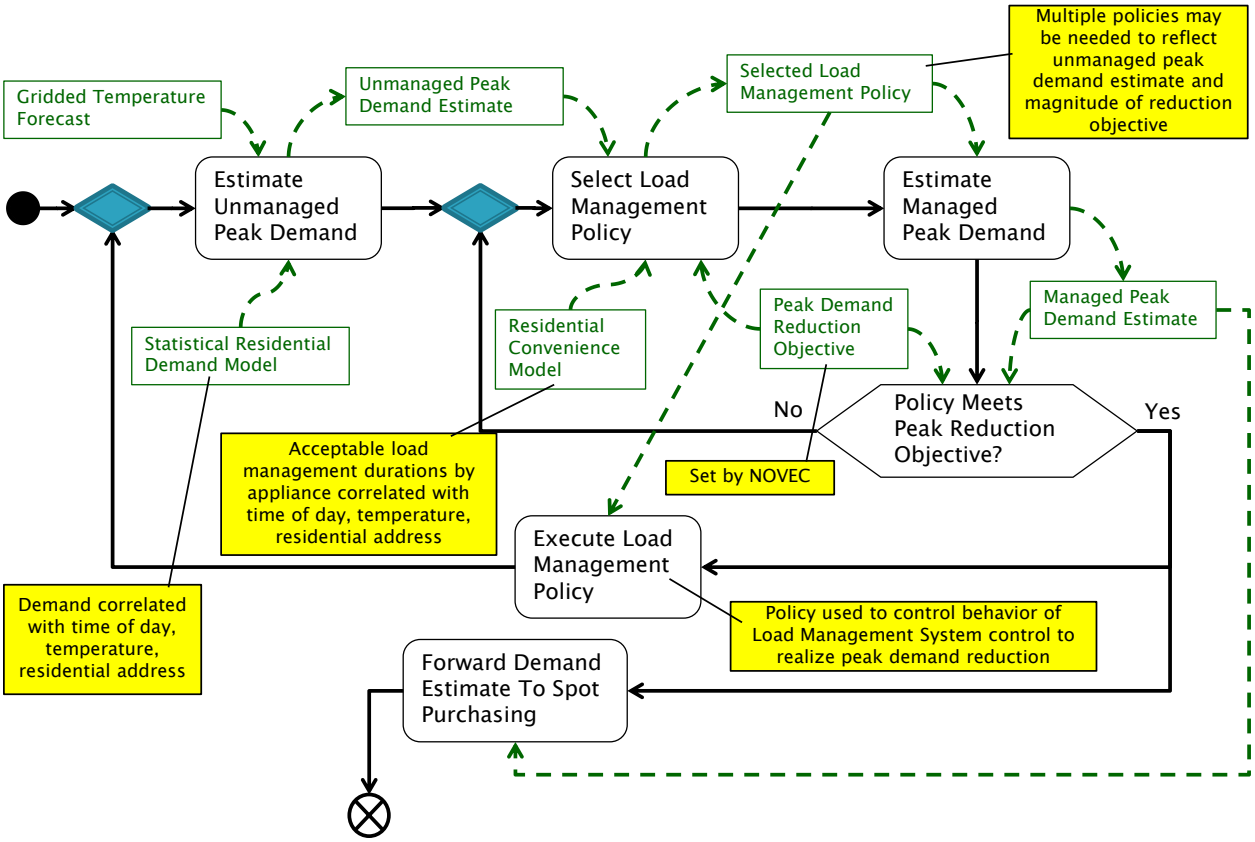

Figure 1 – Load Management System Concept Activity Diagram

9.2 PROCESS DATA MODELS

The process utilizes two data models and a rules model in its operation. The first data model is the Statistical Residential Demand Model (SRDM) which correlates the expected energy demand of individual residences with time of day and temperature. The second data model is the Residential Convenience Model (RCM) that correlates acceptable load management durations by appliance with time of day, temperature, and residential address. Finally, the rules model embodies one or more load management policies in the form of actionable rules that can be utilized by computer programs. The content and structure of Load Management Policy Rules Model (LMPRM) will determined as part of the technology development performed by this project.

9.3 TECHNICAL APPROACH

The technical approach to realizing the optimization process described in section 9.1 consists of the following steps:

- Development of the algorithm to estimate the unmanaged peak demand
- Development of the form and content of a load management policy
- Development of the algorithm to select a load management policy in response to a peak demand reduction objective
- Development of the algorithm to estimate the managed peak demand as a result of a load management policy being enforced
- Development of the Statistical Residential Demand Model and Residential Convenience Model which are required respectively for the proper operation of the peak demand estimation algorithms and load management selection algorithm
- Development of a prototype data input interface to allow the optimization process to use outside temperature versus time data
- Development of a prototype data output format that is conceptually provided to the NOVEC LMS controller
- Development of a prototype data output format that is conceptually provided to the NOVEC spot power purchase system.
- Testing the operation of the realized optimization process using computer simulations of the LMS operating on recorded historical temperature and energy demand data.

9.4 AVAILABLE NOVEC DATA

To facilitate the development of the optimization process, NOVEC has offered to provide data from a variety of sources to be used in algorithm development and model creation. NOVEC has given insight into the data available to the project such as:

- Aggregate monthly load data for all residential customers for the last 2 years
- Hourly cost of power on the spot market for the last 2 years
- Temperature data for the last 2 years

- 15-minute interval data for last 2 summer periods (May 1 - Oct 1) from individual meters
- Sample load curves for various demand scenarios
- Current size of a block of switches that can be shut off in unison during load management
- List of sample dates/times in recent years when load management was implemented
- Technical information on load management switches for air conditioning units and hot water heaters
- The typical size and age of residential homes served by NOVEC.

10 TECHNICAL SOLUTION DELIVERABLES

The technical solution deliverables comprise lab quality prototypes of computer programs, data models, and interfaces.

10.1 COMPUTER PROGRAMS

The deliverable computer programs include the Unmanaged Peak Demand Estimator (UPDE), the Managed Peak Demand Estimator (MPDE), and the Load Management Policy Selector (LMPS). The UPDE provides an estimate of the peak demand without the influence of the Load Management System (LMS). The LMPS selects a candidate load management policy to be used to estimate the managed peak demand. The MPDE provides an estimate of the peak demand that is expected using the LMS to enforce a selected load management policy.

10.2 DATA MODELS

The deliverable data models are the Statistical Residential Demand Model (SRDM), the Residential Convenience Model (RCM), and the Load Management Policy Rules Model (LMPRM). These models were previously described in section 9.2.

10.3 INTERFACES

Three interfaces will be produced to allow the model to interact with the existing NOVEC infrastructure. The first interface will permit the model to take in real time or forecast outdoor temperature data and use it in calculations. The second interface will be a simulated interface that will convey the selected load management policy to the existing load management control system for execution via operation of the residential load management switches. The third

interface will be a simulated interface that conveys managed peak demand estimates to NOVEC's spot power purchasing system.

11 PROJECT WORK BREAKDOWN STRUCTURE

In order to achieve the expected results by the end of this semester, the primary tasks have been broken down into a high-level Work Breakdown Structure (WBS) depicted in Figure 2. The project tasks are broken into four main categories to include Project Management and Reporting, Research, Modeling and Simulation, and Analysis and Recommendations. Project Management and Reporting includes activities such as schedule monitoring and control and deliverable development (e.g. proposal, final report and presentation). The Research task involves collecting background data to better understand the problem and raw data to be used as the basis for model development. Modeling and Simulation contains the build-up to, and development of, the optimization model. Finally, Analysis and Recommendations involves tasks that deal with testing the model against pre-determined scenarios and analyzing the results.

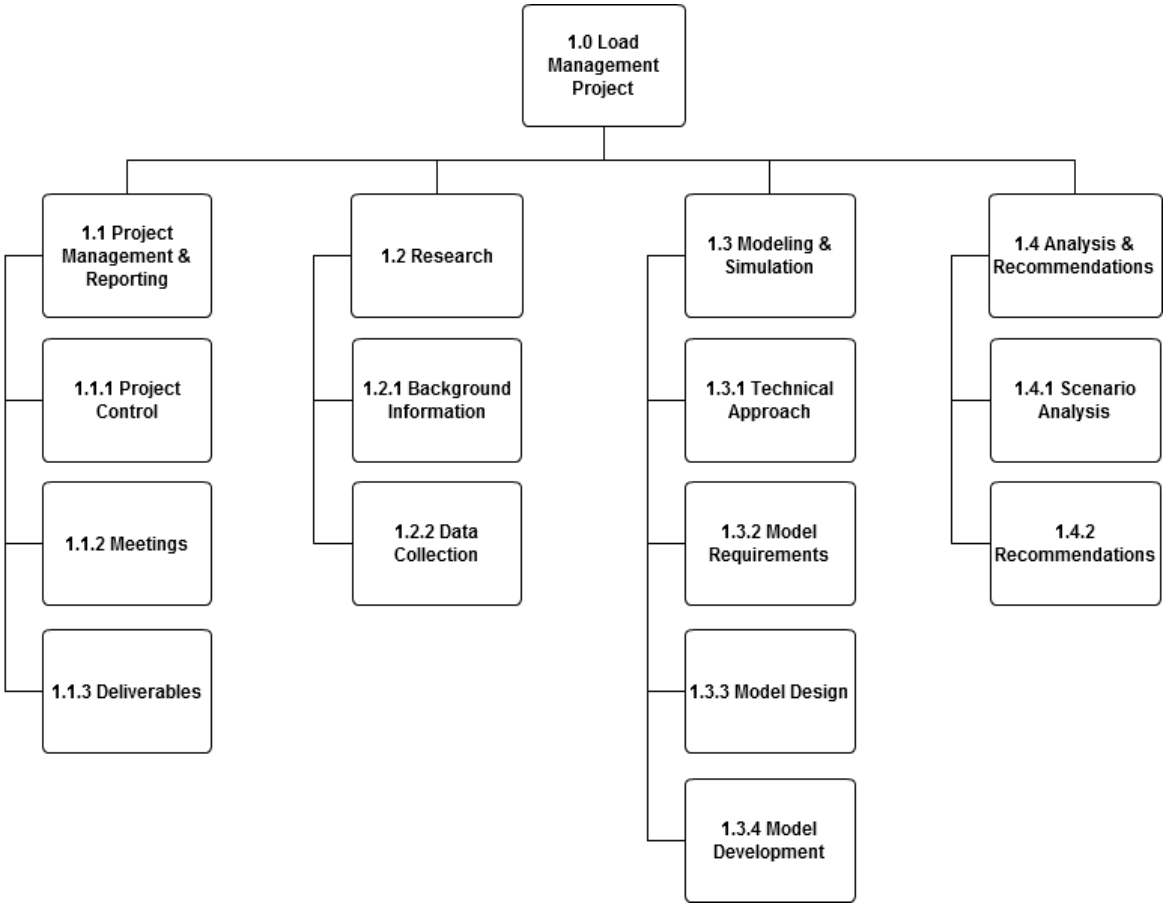

Figure 2 – Load Management Project WBS

12 PROJECT PLAN

The schedule shown below in Figure 3 on page 13 provides further detail regarding tasks and milestones critical to the project's success. The project tasks are scheduled throughout the 14-week semester and are based on an average workload of 10 hours per week per team member. Earned Value Methodology (EMV) will be used to track progress throughout the semester. The team will take partial credit when work is started on an activity and full credit only when the results and milestones are achieved (i.e. the 20/80 technique).

ID	Task Mode	WBS	Task Name	Duration	Start	Finish
1		1	Load Management Project	77 days	Thu 1/26/12	Fri 5/11/12
2		1.1	Project Management & Rep	77 days	Thu 1/26/12	Fri 5/11/12
3		1.1.1	Project Control	71 days	Fri 2/3/12	Fri 5/11/12
7		1.1.2	Meetings	65 days	Mon 2/6/12	Mon 5/7/12
8		1.1.2.1	Team Meetings	65 days	Mon 2/6/12	Mon 5/7/12
23		1.1.2.2	Sponsor Meetings	45 days	Fri 2/10/12	Fri 4/13/12
27		1.1.3	Deliverables	76 days	Thu 1/26/12	Fri 5/11/12
28		1.1.3.1	Project Proposal	15 days	Thu 1/26/12	Thu 2/16/12
33		1.1.3.2	Website	64 days	Mon 2/13/1	Fri 5/11/12
37		1.1.3.3	Progress Reports	16 days	Thu 3/8/12	Thu 3/29/12
40		1.1.3.4	Final Report	29 days	Mon 4/2/12	Fri 5/11/12
46		1.1.3.5	Final Presentation	29 days	Mon 4/2/12	Fri 5/11/12
52		1.2	Research	20 days	Mon 1/30/1	Fri 2/24/12
53		1.2.1	Background Information	10 days	Mon 1/30/1	Fri 2/10/12
56		1.2.2	Data Collection	10 days	Mon 2/13/1	Fri 2/24/12
59		1.3	Modeling & Simulation	37 days	Thu 2/2/12	Sun 3/25/12
60		1.3.1	Technical Approach	16 days	Fri 2/3/12	Fri 2/24/12
63		1.3.2	Model Requirements	17 days	Thu 2/2/12	Sun 2/26/12
68		1.3.3	Model Design	10 days	Mon 2/13/1	Fri 2/24/12
71		1.3.4	Model Development	20 days	Mon 2/27/1	Sun 3/25/12
75		1.4	Analysis & Recommendatio	24 days	Mon 3/19/1	Fri 4/20/12
76		1.4.1	Scenario Analysis	20 days	Mon 3/19/1	Sun 4/15/12
81		1.4.2	Recommendations	9 days	Mon 4/9/12	Fri 4/20/12

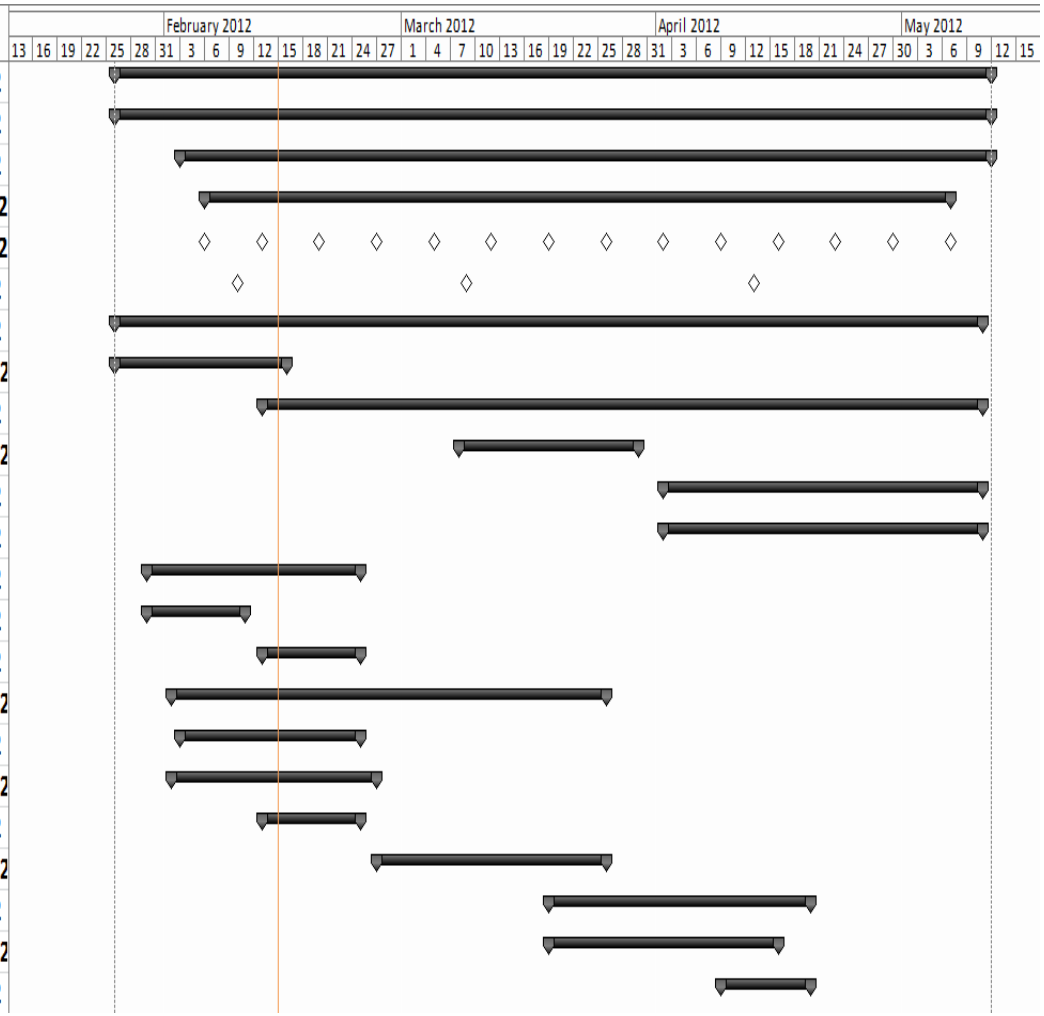

Figure 3 – Load Management Project Schedule