Initial Requirements Study into Intelligent Power Management

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Abstract

This paper presents the outcome of a scoping study addressing requirements for the role of intelligent power management in future and legacy platforms. We highlight a number of non functional systems requirements which have been disseminated from a series of expert's responses to a set of key questions. In addition, a number of benefits and perceived drawbacks regarding the application of intelligent power management are given. The paper concludes with a series of recommendations for future work in the intelligent power management domain.

Keywords: Intelligent Power Management, Requirements, Energy, Autonomous

Introduction

In both the autonomous and non-autonomous domains, systems are becoming more advanced and capable. These advancements in capability tend to manifest themselves as additional platform sensors, active materials, increased computing requirements and missions that may demand persistence and endurance. Thus, as systems advance, the demand from these systems for ever greater energy requirements increases.

Currently this increase in demand is supplied through the use of more, ever larger and heavier energy sources (power plants and batteries). This creates logistical problems with providing energy sources to where they are required, and in charging, storing and maintaining large volumes of these sources. In addition, from a platform perspective, there is a physical constraint on the number of sources which a platform can contain; this along with the weight and size of these sources typically limits a platform's performance.

Alternatively, the increase in demand for power can be mitigated through a reduction in systems capability. Typically this manifests itself as reductions in platform mission duration, performance capabilities, sensing and strike capability.

An aim of intelligent power management (IPM) is to ensure the more efficient and effective use of energy in order to reduce the current dependency for additional or larger energy sources, while not compromising the capability of the platform.

There are a number of ways this could be done, including improvements to the energy efficiency of existing hardware, improvements to the distribution of power through a system, and improvements to battery and source capacitance technology. This paper focuses upon gathering requirements for a system which manages and allocates currently available energy in an optimum way during mission planning and execution.

By optimising the use of energy throughout a mission, we can hopefully gain substantial benefits in platform capability, and reduced logistical overhead.

Definitions

This paper uses the following terms extensively, and for consistency they are defined here.

Intelligent Power Management

An intelligent power management system monitors, predicts and optimises the use of a platforms available energy such that it can be converted into useful power, when and if, it is required by the system.

Energy

The International System of Units [1] defines the unit of energy to be: m2·kg·s-2 which is measured in joules.

The Oxford English Dictionary [2] defines energy to be:

'The property of matter and radiation which is manifest as a capacity to perform work'

The amount of energy used over time is given by the equation:

Energy (joule) = Power (Watts) x Time (seconds)

Power

The International System of Units [1] defines the unit of power to be: m^2 kg s^{-3} which is measured in joules per second.

As an equation, electrical power is given by:

Power (Watts) = Current (amp) x Potential Difference (Volts)

Key Questions

An initial series of key questions regarding the current and future requirements for IPM were posed to experts in unmanned air, land and underwater domains (UXV). The responses to these questions have been used to create a set of non functional systems requirements. The key questions posed to experts were:

1. Would you agree with the given definition of 'Intelligent Power Management'?
2. Why is 'Intelligent Power Management' for UXV required? What type of functionality would an IPM system provide?
3. What level of 'Intelligent Power Management' capability do we currently have onboard our UXV's (our baseline capability)?
4. What do you believe to be the next technological level of 'Intelligent Power Management' capability which would provide benefit to our UXV systems?
5. What do you foresee are the benefits of 'Intelligent Power Management' for UXV systems are?
6. What do you foresee are the drawbacks of 'Intelligent Power Management' for UXV systems are?

These questions are not a complete set, and as such, our conclusions recommend that further questions be posed to system experts in order to fully understand the requirements and functionality of future IPM systems.

Requirements

Non-Functional System Requirements

The responses given by system experts to the key questions have been compiled into a set of non-functional system requirements which are presented in Table 1. These provide high level requirements which an IPM system should satisfy in order to meet the customer's basic expectations.

The following statements define the level of compliance sought:

Shall: Indicates a mandatory requirement

Should: Indicates a desirable requirement

May: Indicates either an optional requirement, or a statement relating to how mandated requirements can be achieved

Table 1: Non function system requirements

		Description
1.0	SHALL	An 'Intelligent Power Management System' shall increase the amount of available electrical energy in a platform's energy source (once a predefined mission has been completed) compared to that which is available when the same mission under exacting environmental conditions is performed without an 'Intelligent Power Management' System.
2.0	SHALL	An 'Intelligent Power Management System' shall not impact up on safety critical aspects of the UXV.
3.0	SHALL	An 'Intelligent Power Management System' shall not cause the UXV to fail any mission objectives which it would have otherwise completed.
4.0	SHALL	An 'Intelligent Power Management System' shall not adversely impact up on the availability of a UXV platform.
5.0	SHALL	An 'Intelligent Power Management System' shall not adversely impact up on the reliability of a UXV platform.
6.0	SHOULD	An 'Intelligent Power Management System' should monitor the systems and sensors of a UXV to identify faults and leakages which reduce the amount of available electrical energy without producing useful power (that which is required by the system).
7.0	SHOULD	An 'Intelligent Power Management System' should increase the platforms capability in performing a particular mission given an initial specified amount of available electrical energy contained or generated from a source.
8.0	SHOULD	An 'Intelligent Power Management System' should increase the UXV's safe operational mission duration.
9.0	SHOULD	An 'Intelligent Power Management System' should provide the mission planner with predictive information regarding the rate of electrical energy consumption (power) throughout the mission.
10	MAY	An 'Intelligent Power Management System' may reduce the carbon footprint of the platform.
11	MAY	An 'Intelligent Power Management System' may predict the power usage of low level sensors and systems, thus enabling the efficient turning on and off of these components.

Benefits

The requirements study highlighted a number of expected benefits in the use of future IPM systems. These benefits are the key drivers in the development of future IPM capability. A subset of the benefits identified is presented below, a full list can be found in [3]:

1. Increased platform capability with regards to mission goals and objectives.
2. Potential reduction in platform weight and size.
3. Increase in platform monitoring capability.
4. Increased platform utilisation and availability.
5. Reduced platform overheads in charging, storing and obtaining power

sources. Consequently this leads to a reduction in logistical overhead.

6. Reduction in the carbon footprint of the platform.

Drawbacks

As well as highlighting potential benefits, the requirements study captured a number of important concerns with the use of IPM systems. These are summarised below, with further detail available in [3]:

1. *Safety*: These concerns centre on an IPM system making autonomous decisions which impact upon the platforms ability to function correctly. This involves the IPM system making incorrect decisions or overstretching the platform, leading to complete system failure which can pose a risk to human health.
2. *Risk of Mission Failure*: These concerns regard a platform failing mission goals due to an IPM system making incorrect or inappropriate autonomous decisions. Because of this concern, IPM is currently perceived to add risk to the reliability, availability and robustness of a platform.
3. *Cost* : These concerns regard the cost of implementing, certifying and proving of IPM systems upon autonomous platforms.

Future Capability Requirements

The key questions posed, enabled us to capture the current 'state of the art' in power management technology, which is deployed upon autonomous vehicles. This, along with the non-functional systems requirements and a benefits / drawbacks analysis enabled us to observe a gap in capability.

The study [3] identified that at present, the accurate predictive modelling of electrical power usage at a platform system level is not performed. While accurate models of engine power usage do exist, models which predict platform systems power usage, based upon a consideration of factors such as the platforms environment, status, component deterioration, sensor usage and mission requirements do not currently exist.

The inability to accurately predict a systems power usage is identified as a gap in capability. Without these predictive models, it may prove difficult to develop an IPM capability that can effectively achieve the given non functional system requirements.

Furthermore, the capability to make or suggest decisions which may utilise available energy in a more efficient or robust manner is currently limited, as this functionality is predicated on the ability to accurately predict systems power usage, which (as stated previously) is not a capability which is currently available.

Conclusions and Recommendations

The study produced a series of non functional system requirements for an IPM system. These requirements highlighted that improvements in IPM technology could lead to substantial reductions in systems energy expenditure and associated logistical overhead, while enabling increases in capability. The study also highlighted concerns regarding the ability of future IPM systems to make autonomous decisions, and the impact this could have upon system safety and mission effectiveness.

The study concluded by suggesting, that while research in IPM should continue in order to provide the benefits highlighted, work in the domain should focus on the development of IPM functions that operate in support of the mission planning system.

The specific recommendations for future research are based upon all the elements presented in this paper. While the non functional systems requirements and benefits highlighted the advantage IPM could bring to a system, the concerns expressed must be considered.

The future capability analysis highlighted a gap in technology which we recommend is addressed. This can be done through the development of accurate and adaptive models which predict a platform's energy requirement throughout a mission.

These models can then be used by either an autonomous or human mission planning and re-planning agent. Initially these models may form the building blocks of a decision support making capability.

In order to facilitate the creation of such a system, a full functional analysis should be undertaken in order to fully understand the functions of the system, its interfaces and capture all key user requirements.

References

[1] A Thompson, B Taylor. *Guide for the Use of the International System of Units (SI)*, 2008

[2] Oxford University Press, *The Oxford Dictionary of Current English*, 1984

[3] Morley B, *SEAS DTC PPEM016 Intelligent Power Management*, February 2009

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