PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter II of the Patent Cooperation Treaty)

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference 631137MDA	**FOR FURTHER ACTION**	See Form PCT/IPEA/416
International application No. **PCT**/NZ2010/000222	International filing date *(day/month/year)* 8 November 2010	Priority date *(day/month/year)* 9 November 2009
International Patent Classification (IPC) or national classification and IPC Int. Cl. ***G06F 11/30*** (2006.01) ***F02B 43/02*** (2006.01) ***G05B 6/05*** (2006.01) ***F01D 17/00*** (2006.01) ***F22B 35/18*** (2006.01) ***G06F 17/13*** (2006.01) ***F01K 13/02*** (2006.01)***G05B 1/11*** (2006.01)		
Applicant EXERGY LIMITED et al		

1. This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of 4 sheets, including this cover sheet.
3. This report is also accompanied by ANNEXES, comprising:
   a. [X] *(sent to the applicant and to the International Bureau)* a total of **6** sheets, as follows:
      - [X] sheets of the description, claims and/or drawings which have been amended and/or sheets containing rectifications authorized by this Authority, unless those sheets were superseded or cancelled, and any accompanying letters (see Rules 46.5, 66.8, 70.16, 91.2, and Section 607 of the Administrative Instructions).
      - [ ] sheets containing rectifications not taken into account by this Authority because they were not available at the time when this Authority began to draw up this report, and any accompanying letters (Rules 66.4*bis*, 70.2(e), 70.16 and 91.2).
      - [ ] Superseded sheets and any accompanying letters, where this Authority either considers that the superseding sheets contain an amendment that goes beyond the disclosure in the international application as filed, or the superseding sheets were not accompanied by a letter indicating the basis for the amendments in the application filed, as indicated in item 4 of Box No. I and the Supplemental Box (see Rule 70.16(b)).
   b. [ ] *(sent to the International Bureau only)* a total of (indicate type and number of electronic carrier(s)) , containing a sequence listing, in electronic form only, as indicated in the Supplemental Box Relating to Sequence Listing (see paragraph 3*bis* of Annex C of the Administrative Instructions).
4. This report contains indications relating to the following items:
   - [X] Box No. I Basis of the report
   - [ ] Box No. II Priority
   - [ ] Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - [ ] Box No. IV Lack of unity of invention
   - [X] Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement
   - [ ] Box No. VI Certain documents cited
   - [ ] Box No. VII Certain defects in the international application
   - [ ] Box No. VIII Certain observations on the international application

Date of submission of the demand 27 July 2011	Date of completion of this report 11 January 2012
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INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

International application No.
PCT/NZ2010/000222

Box No. I Basis of the report

1. With regard to the **language,** this report is based on:

[X] The international application in the language in which it was filed

[ ] A translation of the international application into , which is the language of a translation furnished for the purposes of:

[ ] international search (under Rules 12.3(a) and 23.1 (b)).

[ ] publication of the international application (under Rule 12.4(a)).

[ ] international preliminary examination (Rules 55.2(a) and/or 55.3(a) and (b)).

2. With regard to the **elements** of the international application, this report is based on *(replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report)*:

[ ] the international application as originally filed/furnished

[X] the description:

pages **1-21** as originally filed/furnished
pages* received by this Authority on with the letter of
pages* received by this Authority on with the letter of

[X] the claims:

pages as originally filed/furnished
pages* as amended (together with any statement) under Article 19
pages* **22-26** received by this Authority on **13 December 2011** with the letter of **13 December 2011**
pages* received by this Authority on with the letter of

[X] the drawings:

pages **1/5 to 5/5** as originally filed/furnished
pages* received by this Authority on with the letter of
pages* received by this Authority on with the letter of

[ ] a sequence listing - see Supplemental Box Relating to Sequence Listing.

3. [ ] The amendments have resulted in the cancellation of:

[ ] the description, pages
[ ] the claims, Nos.
[ ] the drawings, sheets/figs
[ ] the sequence listing *(specify)*:

4. [ ] This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since either they are considered to go beyond the disclosure as filed, or they were not accompanied by a letter indicating the basis for the amendments in the application as filed, as indicated in the Supplemental Box (Rules 70.2(c) and (*c-bis*)):

[ ] the description, pages
[ ] the claims, Nos.
[ ] the drawings, sheets/figs
[ ] the sequence listing *(specify)*:

5. [ ] This report has been established:

[ ] taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rules 66.1(d-*bis*) and 70.2(e)).
[ ] without taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rules 66.4*bis* and 70.2(e)).

6. [ ] Supplementary international search report(s) from Authority(ies) _____ has/have been received and taken into account in establishing this report (Rule 45bis.8(b) and (c)).

* *If item 4 applies, some or all of those sheets may be marked "superseded."*

Box No. V **Reasoned statement under Article 35(2) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement**

1. Statement

Novelty (N)	Claims	**1-6**	**YES**
	Claims	**NONE**	**NO**
Inventive step (IS)	Claims	**1-6**	**YES**
	Claims	**NONE**	**NO**
Industrial applicability (IA)	Claims	**1-6**	**YES**
	Claims	**NONE**	**NO**

2. Citations and explanations (Rule 70.7)

NEW CITATIONS (Informal Search in Chapter II)

D1 MORINI, M. et al., "DEVELEOPMENT OF A ONE-DIMENSIONAL MODULAR DYNAMIC MODEL FOR THE SIMULATION OF SURGE IN COMPRESSION SYSTEMS", ASME TURBO EXPO 2006, May 8-11, Barcelona, Spain

D2 PARASHAR, M. et al., "CONTINUUM MODELING OF ELECTROMECHANICAL DYNAMICS IN LARGE-SCALE POWER SYSTEMS"
IEEE Transactions on Circuits and Systems I Sept. 2004, Vol. 51 No. 9

Note: The opinion given here is from the IPEA and is based on an informal search in Chapter II and not on any International Search. No International Search was provided for this application because the original claims defined excluded subject matter PCT Rule 39.1 (i) scientific and mathematical theories. National states are advised to apply the local national laws and search or examine the Article 34 claims as if no search has been done. This informal opinion on Novelty and Inventive Step is in relation to the amended Article 34 claims and is published to aid the applicant in drafting searchable claims.

NOVELTY (N)

Claim 1 is to a computer implemented method of controlling any energy conversion plant. Claim 1 contains a preamble (page 22 lines 3-16) and features a) to k). The preamble is considered generic and therefore cannot contribute to a patentable invention.
Features a), b), e), h), i), j) and k) are considered well known steps in the field of digital control systems theory and design. Combining them does not appear to be new.
However no single document discloses all of the features of claim 1 explicitly therefore claim 1 is novel.
Features c), d), f), g) were searched alone and no single document discloses all of those integers, therefore this part of claim 1 is also novel on its own.
For at least these reasons the IPEA is of the opinion that if a search were conducted that there are no novelty destroying citations relevant to the Article 34 claims.

Continued in Supplemental Box 1)

Supplemental Box 1) Continuation of Box V

INVENTIVE STEP (IS)

There are many features in claim 1 that amount to common general knowledge in mathematical, scientific or theoretical documents. However these documents generally do not also disclose **a practical application** to the comprehensive control and optimisation of an energy conversion plant. State of the art approaches (at the applicant's priority date) that do publish practical applications of control system theory and optimisation of power plants appear to use computational fluid dynamics solvers for the working fluids. The present application uses a different approach that requires less computation resources and therefore involves an inventive step. In particular feature f) of claim 1 does not appear to be an obvious method step given a fair reading of the prior art.

Therefore claims 1-6 appear to involve an Inventive Step when the prior art of record is combined in an obvious manner.

INDUSTRIAL APPLICABILITY (IA)

The invention defined in claims 1-6 is considered to meet the requirements of Industrial Applicability under Article 33(4) of the PCT because it can be made by, or used in, industry

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INTELLECTUAL PROPERTY

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TOTAL PAGES	6

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13 December 2011

IP Australia
Patent Office
PO Box 200
Woden ACT 2606
AUSTRALIA

RESPONSE TO WRITTEN OPINION
Exergy Limited
International (PCT) patent application PCT/NZ2010/000222
System and method for maximising thermal efficiency of a power plant
Our ref 631137 MDA/mjw

We reply to the written opinion mailed 7 September 2011.

The stated deadline is 7 November 2011. We understand the inventor has been in direct contact with the examiner and has obtained an extension.

The applicant proposes new claims focussed on different aspects of the invention. We propose to cancel all current claims and substitute new claims 1 to 6. We attach revised pages 22 to 26.

We understand these claims have been prepared directly by the inventor in consultation with the examiner.

Yours faithfully

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CLAIMS

1. A computer implemented method of controlling any energy conversion plant, in particular power plants of all kinds, having a plurality of measured parameters (which may include temperatures, pressures, partial pressures, mole numbers, as well as flows ,in and out electrical and/or mechanical powers, position of valves and other actuators), that maximizes the plant's thermal efficiency with respect to a subset of plant's measured parameters which can be manipulated, hence termed Variables, subject to operational structural financial and environmental constraints; this constrained maximization is called optimizing; said computer is either integral part of the plant's control system (DCS or other) in the sense that it both reads measured parameter from the DCS's Data Acquisition System (DAS) and writes the Variables maximizing values into the DSC as set-points (closed loop optimization), or just reads measured parameter from the DAS whilst human operators apply maximizing value of the Variables as set-points or by modifying the plant itself (open loop optimization), said method constitutes the following steps:

   (a) Determine set of all relevant measured thermodynamic properties throughout the plant (e.g. temperatures, pressures, partial pressures, mole number, liquid and gas flows and electrical input and output values position of valves and other actuators), and its Variables subset (that is, those measured parameters which can be independently manipulated), by reading them via an interface with the DAS, or manual input,
   (b) derive from the measured parameters in accordance to step (1a) and corresponding thermodynamic properties (e.g specific volume enthalpy and entropy), the state of the plant which constitutes all relevant thermodynamic properties throughout the plant, as well as energy mass and entropy flows, temperatures, pressures, partial pressures, mole numbers, liquid and gas flows and electrical input and output values, real velocity vector fields, by way of relevant balance equations and particular expressions;
   (c) from the plant state determined in step (1b) partition the plant into a finite number of real, irreversible physical continuums in the context of continuum-mechanics, which may or may not deliver useful work, and which correspond to discontinuities of measured and derived parameters making up the state of

the plant as established in step (1b), and satisfying conservation-of-mass condition(s),

(d) construct an isometric (in the thermodynamic metric) map in the context of differential geometry, of each real continuum as established in step (1c) from the thermodynamic manifold which is spanned by thermodynamic coordinates (for example pressure temperature and chemical potentials) and time, to a region of the Galilean manifold spanned by the spatial and time coordinates (for example Cartesian x,y,z,t),

(e) construct the plant model using the partition into physical continuums determined in accordance to step (1c) and in accordance of the physical real arrangement of the plant's actual hardware , as interfacing (i.e incedenting) physical continuums, exhibited as a graph in the context of graph theory which can be reduced to a planar graph, wherein each boundary plays the role of an edge and each continuum the role of a node,

(f) convert each partitioned real, irreversible physical continuum into a (virtual) corresponding reversible continuum or Reversible Masking of the real continuum, subject to the constraint(s) that the real continuum and reversible continuum assume the same boundary values of thermodynamic properties in accordance to all previous steps and that their derivatives are continuous and equal at the boundaries, as well as mass-flow-rate, such that the partitioned irreversible real continuums which are governed by a system of conventional balance equations and constituent (phenomenological) equations, are converted into partitioned Reversible Maskings substitute which are governed by a system of (partial) differential equations excluding any constituent equations, but including either the equation of Thermodynamic Geodesic Field (TGF) in the thermodynamic metric, or a direct Reversible Energy Conservation (REC), uniquely describing the reversible continuum (called a Mathematical Model of the reversible continuum),

(g) construct an equivalent reversible (virtual) plant by mapping the partitioned Reversible Masking substitute equations from step (1f) into the plant model constructed in step (1e), such that the graph of step (1e) is maintained, that is, map the partition of the real plant of irreversible real continuums, into a partition of Reversible Maskings substitute equations, with the same incidence matrix in the context of graph theory,

(h) solve the mapped equations from step (1g) for the current plant state in terms of velocity (vector) fields across the reversible continuums and store the values of the solutions within the spaces defined by the reversible continuums,

(i) construct the objective function (called Loss) to be minimized by a surface integral of kinetic energy obtained from the velocity field derived according to step(1h) over the boundary of each Reversible Masking, inputting to the (numerical) integration the velocity field, density field(s) of (1e) values at the boundary, outputting the difference in kinetic energy between boundaries where matter leaves and enters the Reversible Masking, subtracting from the sum of all kinetic energy increment the actual work delivered by the real plant,

(j) simulate the plant using the solved equations from step (1g) using the reversible model and adjust the control set-points in the simulation to determine the Variables (control inputs) defined in 1 that correspond to the minimization of the Loss constructed in step (1i) resulting in maximizing the efficiency of the plant according to a predetermined objective function,

(k) apply the Variables (control inputs) derived according to step (1j) that minimize the objective function constructed according to step (1i) to the real thermal power plant.

2. A method to generate a revised state of the plant and reversible velocity fields due to varying the Variables subset defined in claim (1), based at least partly on a (power) plant configuration in accordance to step (1e), superimposed by the Reversible Masking in accordance to step (1f), and consequent reversible plant in accordance to step (1g) comprising a solver as follows :

(a) Euler's balance of momentum equation; and

(b) the conservation of mass equation ; and

(c) the reversible conservation of energy (REC) equation; and

(d) the thermodynamic equations of state; or

(e) the thermodynamic geodesic field (TGF) equations,

(f) and a module to carry out the numerical solution of the simultaneous equations (2a) to (2f) subject to revised boundary conditions based at least partly on Central Schemes methods, or Method of Lines, or reduced versions of these thereof.

3. A simulator constituting a readable media module storing the data that flows from the numerical solution module defined in (2f) which simulates the thermodynamic properties of the real plant.

4. A method to derive kinetic energy differences across each of the reversible continuums defined in step (1f), from the data flow of the reversible velocity field(s) computed by the solver defined in claim (2), which is fed into a module of numerical integration of kinetic energy around the surface of each reversible continuum.

5. A method to obtain the objective function constituting the sum of all kinetic energy integrals, of all Reversible Maskings defined in step (1f).

6. An apparatus for any one of the preceding claims herein comprising a (power) plant thermal efficiency constrained-maximization (optimization), the apparatus configured to implement the method of claim 1, that is, configured to obtain the current state of the plant from available measured data; obtain the Variables subset of the measured data defined in claim 1; apply a set of constraints to the Variables; generate a revised state of the reversible power plant, where the reversible plant is defined in step (1g), as a function of the revised set of Variables, the generation based at least partly on mathematical model of the reversible continuum (or Reversible Masking) of step (1f);and test the revised set of Variables for convergence, comprising the following modules and data flows:
   (a) interfacing module with the DAS or exercising manual input in accordance with claim (1), to determine initial values of the set of all relevant measured thermodynamic properties throughout the plant in accordance to step (1a); the measured data and the Variables subset flow to readable media modules;
   (b) a module that generates the initial (current) state of the plant as defined in step (1b), from the measured parameters in accordance to step (1a) which is stored in a module depicted in (6a) and the corresponding thermodynamic properties (e.g specific volume, enthalpy and entropy),
   (c) a module constructing the partition into physical continuums in accordance to step (1c), based at least partly on checking each combination of boundary-surfaces of mass-flow entering the continuum against all combinations of boundary-surfaces of mass-flow leaving the continuum for conservation of

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mass; as a result each continuum is reduced to cylindrical symmetry (1-dimensional), and furthermore the plant is exhibited as a planar graph in the context of graph theory, wherein each boundary of interfacing (i.e incedenting) physical continuum plays the role of an edge, and each continuum the role of a node, and furthermore the resultant plant model is as defined in step (1e),

(d) a convergence tester module which can be part of the minimizer procedure (like Cobyla), within which the solver of claim (2), the simulator of claim (3), and the objective function in accordance to claim (5), are applied in that order to the plant model of module (6c) and the revised set of Variables, which is then examined to reach a variance less than a threshold variance; if the convergence test fails, then the revised numerical values of the objective function and the Variables and state of the plant which are stored in the simulator module of claim (3) above, are fed into

(e) a minimizer module like Cobyla which generates revised values of the set of Variables defined in claim (1) which are fed into the mathematical model of the reversible plant (that is the solver of claim (2)), and

(f) repeating convergence testing described in (6d) of generating yet another revised state of the plant and reversible velocity field, and testing the resultant revised objective function as defined in step (1i) and generated in accordance to claim (5), and testing the revised set of Variables for a variance less than a threshold variance in the convergence tester module (6d); if achieved, then

(g) physically applying continuously the Variables values generated in module (6f) which is the Optimizer output, to the (real) energy conversion plant, by way of closed loop optimization or open loop optimization in accordance with claim (1), necessarily resulting in minimizing the objective function (Losses) defined in step (1i), and generated in accordance to (6d), resulting in the maximizing of the thermal efficiency of the real plant; if a constraint in the context of claim (1) is a given power output then said maximizing of thermal efficiency will manifest itself as the minimizing of fuel consumption, whilst if the fuel consumption is rather dictated as an external constraint, then said maximizing of thermal efficiency will manifest itself as the maximizing of power output.