PhD Proposal 1

Title: eFactory for Flywheel Energy Storage for the Vertical Wind Turbine and Rail Car – Solid Modelling, Simulation and Optimization and Reverse Engineering

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Motivation Question

This research project aims to answer the following question:

> *How could I create an eFactory for future Engineering Generation to enable them to visualize all the optimum details design and FEA of the Flywheel Energy Storage System, the Vertical Wind Turbine and the Rail Car, so that they can manufacture these three prototypes by simulation for a real factory production, using reverse engineering for decreasing the air-pollution, saving funds and creation of jobs for future generation in Australia?*

Objectives, Approaching the Research Topic and Expected Results

1. The increasing focus and intermittent nature of renewable sources increases the demand for energy storage, such as flywheels. I aim to create an eFactory, which motivates engineers to simulate the design [CAD], FEA and CAM for FESS, VWT, and Rail Car and do not blindly spend a lot of time reading for cognitive design and strain analysis over 2D online pictures and texts for FESS. This is more effective on kinaesthetic learners. See phases of eFactory so far: www.ewindfly.net/store/p1/eFactory.html creation of this eFactory is a novel idea. When population in capital cities increases FESS, which is highly reliable, safe and has long life, is energy efficient and non-polluting would be in demand. FESS market would grow 20% [6 – link 9]. eFactory is to train engineers with these modern learning objectives. Learning Resources in eFactory would be about FESS and not the traditional battery storage, etc. This is a novel idea, which does not exist in many learning resources for engineers training nowadays.
2. FESS has high power output, can cyclic discharge to zero energy, has much higher charging and discharging rate, also it has large energy storage capacity. FESS has high power density and high energy density. FESS power compensation is very effective [6-link 8-slide 14]. The life time of the FESS is almost independent of the depth of the charge and discharge cycle. FESS has a short recharge time. Unlike conventional coal and gas generators, which have an efficiency ratio of 35-40%, FESS operates at upwards of 85-90% efficiency [6-link 3-para.4 for efficiency]. In this part there would be devising novel Environmental legislation, which accommodates the risk

management techniques for these hazards associated with FESS at work place or at home. Also, the most advanced world eLearning resources would be used for eFactory such as TurboCAD [does not need $10,000 licence, is only $100] for Solid Modelling, SimWise-4D for Finite Element Analysis [does not need experience to work with as an engineer]. This novel methodology would decrease the cost of eLearning and training, and it would provide a cognitive learning for engineers, so it can create jobs for most engineers and would help them to use all their senses for understanding these FESS features.

3. The power output from solar photovoltaic (PV) depends on the strength of sun rays, which vary according to the time of the day and the amount of cloud cover. Managing this variability can be overcome using flywheel technology, which can stabilize frequency and voltage based on requirement. [6 – link 10-para.2] [6-link 11]. I have installed a 5 KW solar power, which you can see in eFactory web page: www.ewindfly.net/store/p1/eFactory.html I would use this solar power for eFactory to demonstrate this feature of the FESS by connecting the solar power to the FESS and monitoring and how FESS can manage this variability, with engineers use all senses to understand. Two-way audio of the video conferencing is the novel methodology enabling engineers to ask questions from the trainer using eFactory.
4. No periodic maintenance is required for FESS, it is easily and inexpensively maintained. FESS is not sensitive to temperature since they are operating in a vacuum containment [6-link2-slide 17]. See Fig. 2. I would supervise Apprentices in CNC Course to manufacture the vacuum containment part using CNC Machine. eFactory method would use an individual learning plan, system for identifying skill needs of the Apprentice, Work-based learning pathways, eLearning resources such as video conferencing – Two-way audio, self-evaluation, self-evaluation and ICT. The novel eFactory would be assessed by PhD Supervisor through two-way audio IP Video Conferencing – Skype Business and Smart TV. Then eFactory would be used for training of thousands of Apprentices in the world to be productive in advanced electro-mechanical energy storage system for renewable energy and Rail way charging stations.
5. Creating Solid Modelling for FESS for VWT by application of the world class software TurboCAD to be able to manufacture optimum prototypes of FESS and VWT and decrease the repetitive manufacturing cost [9]. TurboCAD would be used for design, not SolidWorks/AutoCAD. The software is cheap, much better than the older brands and is world rank in reviews. Technical support for the software is free and does not need $10,000 licence, only $100 for each user to buy! The research aims to make a Nanotube rope, which would be used in manufacturing of the wheel of the FESS. Various weaving type for Nanotube would also be tested. Also, another Steel rim and fibre glass rim, and Kevlar rim would be tested for comparison. The FESS difference with

other products would be that this one can be customised for power Output by adding and decreasing rims of Flywheel. FESS has a DC Generator and not an AC one.

6. Linking the Finite Element Analysis [FEA] of the FESS parts to software SimWise – 4D to create a simulation for movement and demonstration of stress and strain analysis of the FESS to be able to visualise how FESS high speed can create risk of defragmentation and be able to study ways of decreasing the impact of this risk, such as using stronger materials for FESS rim and shaft, or a better bearing [9]. ANSYS is not used, as reviews show this software is better than all previous software's by a 40 years experienced engineer in this FEA field. Testing the FESS with variety of rims of different materials and adding to number of FESS rims to measure radial and Hoop strains with the most advanced spin test meters. Also testing the rim by Nanotube rope or just Nanotube with various weaving pattern. See figures (5-6), (17-21), (24-26) and (28-29) by typing BT6 in search box of www.ewindfly.net or see [12]. Design of assessment instruments and tools for all materials used in this FESS. Type BT2 in search box of www.ewindfly.net to read more about Materials in this objective.
7. Changing the AC Generator of FESS to Brushless DC Generator to study the Cogging torque between the Generator and Flywheel Coupling to prevent risk of fracture, therefore decreasing the operational cost. Also customising the Flywheel rim and VWT blades to be able to customise the FESS Power Output. Analysing the effect of FESS in distribution of frequency of the variable power based on Australian coastline city, Analysis and control of FESS for the VWT [6 – links 88-89]. VWT would be built with primitive tools and is wooden [TEAK] and decorative for marketing reason. Please see link: www.ewindfly.net/store/p1/eFactory.html and see item 7 for wind turbine manufacturing in **eFactory** page.
8. Decreasing the Electricity bill of the consumers, decreasing the Generation fuel cost of electricity, eliminating the need to install Generation Capacity, the avoided or reduced cost associated with building and owning that generation equipment, decrease in labour cost, increase in trade jobs, decrease in shipping cost and time of importing products, increase in speed of FESS Technology transfer, and increase in production and implementing reverse engineering to boost up innovation in electro/mechanical Clean Energy Products by applying Project Management Techniques [10], Using my Graduate Certificate in TESOL to write and publish my 6 articles in the form of Ebot, Using eLearning to produce video conferencing eFactory simulation of the prototypes manufacturing and testing activities to promote advanced work based training for Engineers and Technicians in this field. To see EBOT file, please type **BT11** in search box of www.ewindfly.net

Methodology

Project Management Practice learned at South Metropolitan TAFE [2016-2018], Solid Modelling using TurboCAD software (2018), FEA Simulation using SimWise 4-D, Purchasing some, not all parts for prototypes from online retailer [Such as magnetic bearings], Using my Certificate IV in Training & Assessment [2016] to supervise CNC Apprentices at SMT-Midland to manufacture the shaft, part of the rim and vacuum case of the FESS by CNC and/or Lathe machine [7-links 1-8], getting help from electrical engineering academics to learn how to build a FESS controller after literature survey [6 – links 88-89], building or buying a brushless DC generator [7]. eLearning Design in Adult Education is a wrap for above technologies for educating future generation engineering students using a product which I call it **eFactory:**

www.ewindfly.net/store/p1/eFactory.html

Schedule

To see WBS, Gantt Chart, Milestones and Overview of the FESS for VWT Project, please type BT3 in search box of www.ewindfly.net , or see "Work Break Down Structure" of the "FESS for VWT" [13] and the Gantt Chart in pages 7-8.

Background

Most Marketing specialists suggest that by 2020, demand for Flywheel Energy Storage System [FESS] would increase 19.6% globally. Experts suggest FESS be used in Micro-grid, because in small flywheels [2-6 KW] 20-30 Seconds FESS helps in keeping the power on in case it turns off. However up to 2017, the producers have achieved reaching to the 4 hours FESS helping the power be on when it shuts down. Four hours is the best FESS Performance. Therefore, today is the best point of history if any Australian academic wants to start this research for the second time. Some experts advise that under 6000 – 7000 rpm, it is cheaper to have a steel flywheel rather a risky composite flywheel, which might disintegrate, also maintenance is cheaper. Some suggest Nano-Tube material instead of carbon fibre glass for the wheel rim.

Review of Relevant Research in the Field

> *PJM Interconnection projects that just a 10-20% reduction in its frequency regulation capacity procurement made possibly by additional storage projects – could result in $25-50 million in saving to residential, commercial and industrial consumers" [1]*

The U.S. Energy Storage Industry comprises hundreds of companies and thousands of American workers building commercial energy storage systems throughout the country [1]

The above two quotes from the U.S. – Department of Energy, are the facts proving that in Australia, Flywheel Energy Storage System can create thousands of jobs for Australian workers and companies in building commercial energy storage systems, also over $50 million dollars would be saved for Australian consumers for each big company, which tries to reduce its costs by additional storage projects. Ensuring electricity service without interruption, such as UPS, is

a common use of energy storage. If the power outage last more than a few seconds, the Energy Storage System provides enough power and energy to ride through outage. Also, an on-site storage is a mean for consumers to manage their electricity bill. They can use the storage if their power is not reliable or is low quality. Also, merchant power can make money by storing energy in off peak time of the day and selling it in peak time of the day more expensive. Power companies' primary objective for use of storage is to reduce the need and cost for generation equipment. Reduced need and / or cost for generation fuel and reduced wear on and longer life of generation equipment drive energy-related cost reduction.

"Electric Energy time-shift entails storing of electric energy when energy use and value are low, so that energy can be used or sold, later, when energy use and value are high." [2]

"If Storage use reduces the need to install generation capacity, then the benefit from storage is the avoided or reduced cost associated with building and owning that generation equipment". [2]

"Consumers can benefit from energy storage by:

1. Electricity bill management
2. Reduced / avoided losses due to electric service quality and outages.

If the end-user uses the UPS, the benefit is the cost that would have been incurred during electric service outages without the UPS such as lost employee productivity and lost sales". [1]

"Traditional energy sources-like coal and natural gas power plants-have to be turned on and off as demand fluctuates and are almost never operating at peak performance. This means that energy not only costs more, but pollutes more, than is necessary to meet out energy needs. And the slow ramp up time of these bulk generation facilities means they cannot respond to spikes in demand in real time, potentially leading to brownouts and poor power quality. Adoption of renewable energy resources are linked to energy storage applications. These energy sources are intermittent in nature, producing energy when the sun is shining and the wind blowing. By storing the energy produced and delivering it on demand, these clean technologies can continue to power out grid, even when the sun has set, and the air is still-levelling out jumps in output to create a continuous, reliable stream of power throughout the day. Large scale energy storage allows today's electricity system to run significantly more efficiently and that greater efficiency means lower prices, less emissions and more reliable power" [3]

"Flywheel Energy Storage System (FESS) is an electromechanical energy storage system which can exchange electrical power with the electric network. Typically, users of high- speed flywheels must choose between two types of rims: solid steel or carbon composite. The choice of rim material will determine the system cost, weight, size, and performance. Composite rims are both lighter and stronger than steel, which means that they can achieve much higher rotational speeds. The amount of energy that can be stored in a flywheel is a function of the square of the RPM making higher rotational speeds desirable. Currently, high-power flywheels are used in many aerospace and UPS applications. Today 2 kW/6 kWh systems are being used in telecommunications applications. For utility-scale storage a 'flywheel farm' approach can be used to store megawatts of electricity for applications needing minutes of discharge duration, such as telecommunications. The amount of energy that can be stored is proportional to the object's moment of inertia times the square of its angular velocity. To optimize the energy-to-mass ratio, the flywheel must spin at the maximum possible speed. Rapidly rotating objects are

subject to significant centrifugal forces however, while dense materials can store more energy, they are also subject to higher centrifugal force and thus may be more prone to failure at lower rotational speeds than low-density materials. Therefore, tensile strength is more important than the density of the material. Low-speed flywheels are built with steel and rotate at rates up to 10,000 PRM. More advanced FESS achieves attractive energy density, high efficiency and low standby losses (over periods of many minutes to several hours) by employing four key features:

1. Rotating mass made of fibre glass resins or polymer materials with a high strength-to-weight ratio,
2. A mass that operates in a vacuum to minimize aerodynamic drag
3. Mass that rotates at high frequency, and
4. Air or magnetic suppression bearing technology to accommodate high rotational speed.
5. an electrical machine
6. back-to-back converter
7. DC link capacitor

Advanced FESS operate at a rotational frequency more than 100,000 RPM with tip speeds more than 1000 m/s. FESS are best used for high power, low energy applications that require many cycles". [5] For the advantages and disadvantages of FESS please type BT8 in search box of www.ewindfly.net [14]

References

1. http://energystorage.org/energy-storage/energy-storage-technologies
2. http://energystorage.org/energy-storage/energy-storage-benefits/benefit-categories
3. http://energystorage.org/energy-storage/technologies/flywheels
4. Review of Flywheel Energy Storage Systems structures and applications in power systems and microgrids
5. http://energystorage.org/energy-storage/storage-technology-comparison/thermal
6. www.ewindfly.net/flywheel.html

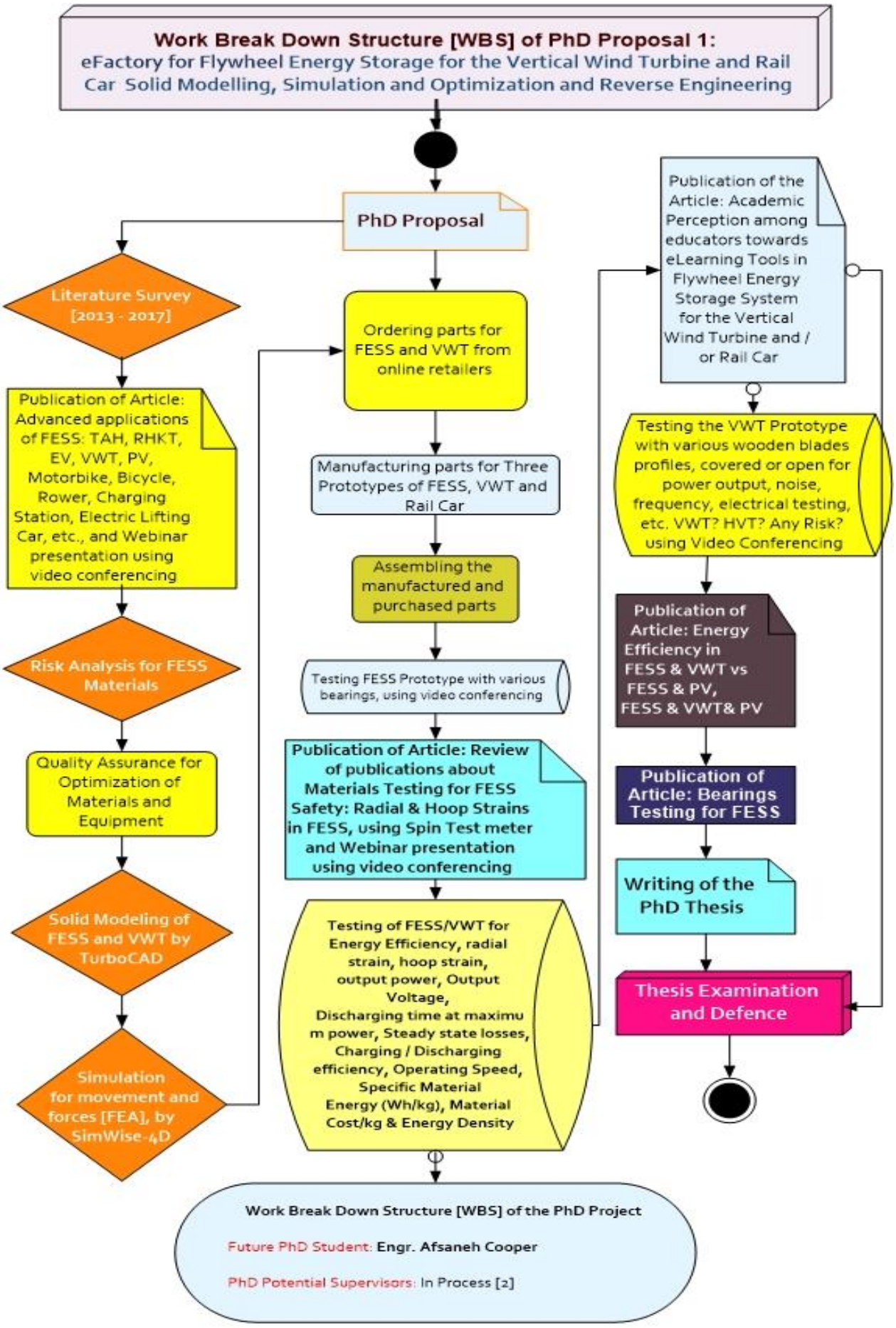
   90 links to "2016 web pages" about flywheel energy storage system

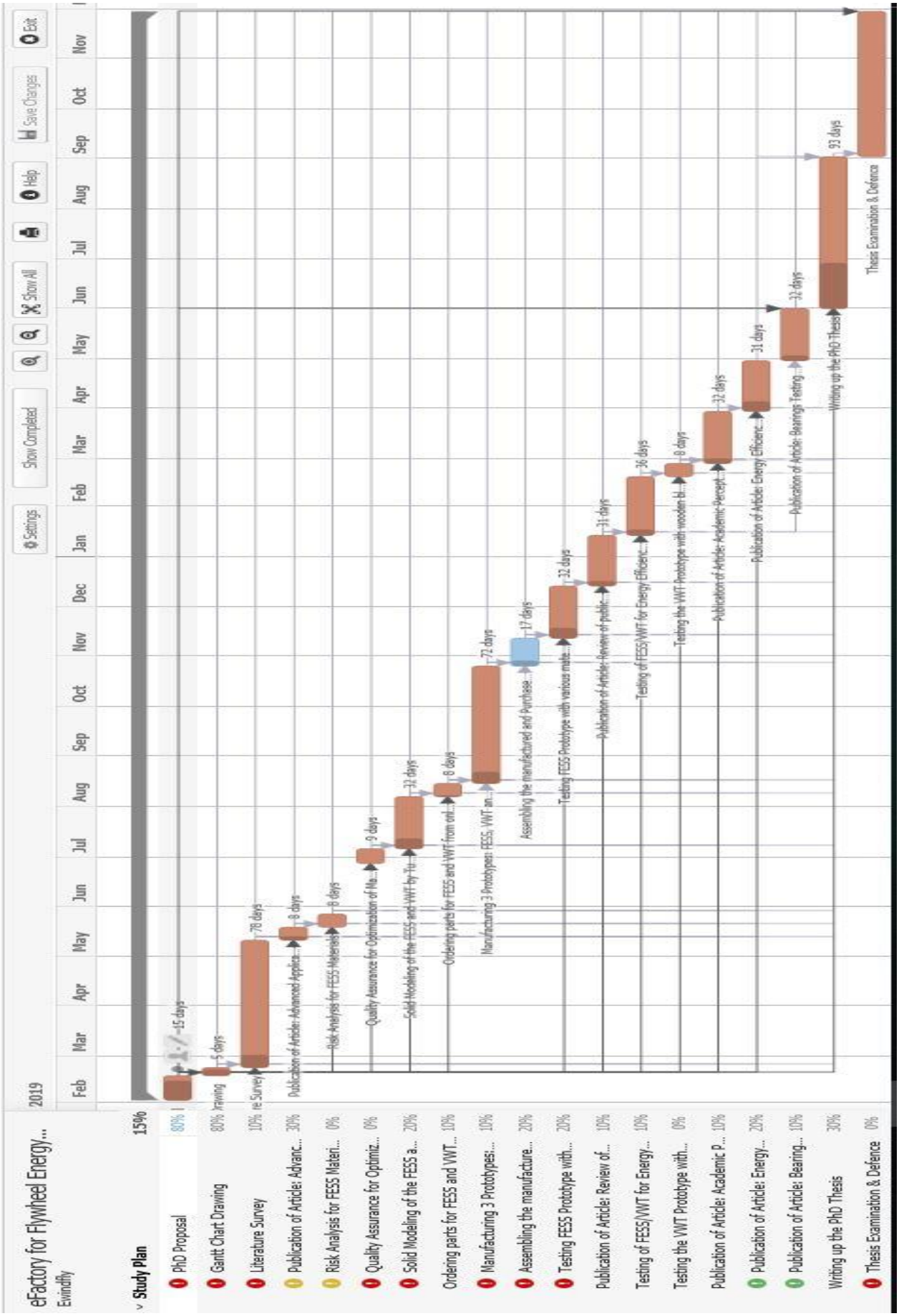
7. www.ewindfly.net/fessvideos.html Flywheel Energy Storage 76 Videos
8. www.ewindfly.net/fessgallery.html

   Gallery of Flywheel Energy Storage System

9. For seeing Videos, Gallery, links about this research, Figures which was referred in this Proposal, Work Break Down Structure for this Project and SimWise-4D video, please type BT7, BT5,BT4, BT6, BT3, BT1 one at the time in Search box of www.ewindfly.net
10. www.ewindfly.net/pmptools.html 16 Project Management Tools
11. https://youtu.be/RLIiKdqxsfQ
12. www.ewindfly.net/figures.html (Figures 1 – 31)
13. www.ewindfly.net/wbsfess.html (ClickChart – Tasks List)
14. www.ewindfly.net/fessadvantages.html (Advantages and disadvantages of FESS)

To see all my PhD Proposal References in one website, please download file: **EBOT** by typing **BT11** in search box of www.ewindfly.net and finding the web page.


Work Break Down Structure [WBS] of PhD Proposal 1:
eFactory for Flywheel Energy Storage for the Vertical Wind Turbine and Rail Car Solid Modelling, Simulation and Optimization and Reverse Engineering
PhD Proposal
Literature Survey [2013 - 2017]
Publication of Article: Advanced applications of FESS: TAH, RHKT, EV, VWT, PV, Motorbike, Bicycle, Rower, Charging Station, Electric Lifting Car, etc., and Webinar presentation using video conferencing
Risk Analysis for FESS Materials
Quality Assurance for Optimization of Materials and Equipment
Solid Modeling of FESS and VWT by TurboCAD
Simulation for movement and forces [FEA], by SimWise-4D
Ordering parts for FESS and VWT from online retailers
Manufacturing parts for Three Prototypes of FESS, VWT and Rail Car
Assembling the manufactured and purchased parts
Testing FESS Prototype with various bearings, using video conferencing
Publication of Article: Review of publications about Materials Testing for FESS Safety: Radial & Hoop Strains in FESS, using Spin Test meter and Webinar presentation using video conferencing
Testing of FESS/VWT for Energy Efficiency, radial strain, hoop strain, output power, Output Voltage, Discharging time at maximu m power, Steady state losses, Charging / Discharging efficiency, Operating Speed, Specific Material Energy (Wh/kg), Material Cost/kg & Energy Density
Publication of the Article: Academic Perception among educators towards eLearning Tools in Flywheel Energy Storage System for the Vertical Wind Turbine and / or Rail Car
Testing the VWT Prototype with various wooden blades profiles, covered or open for power output, noise, frequency, electrical testing, etc. VWT? HVT? Any Risk? using Video Conferencing
Publication of Article: Energy Efficiency in FESS & VWT vs FESS & PV, FESS & VWT& PV
Publication of Article: Bearings Testing for FESS
Writing of the PhD Thesis
Thesis Examination and Defence
Work Break Down Structure [WBS] of the PhD Project
Future PhD Student: Engr. Afsaneh Cooper
PhD Potential Supervisors: In Process [2]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Study Plan 15%
PhD Proposal 80%
Gantt Chart Drawing 80%
Literature Survey 10%
Publication of Article: Advanc... 30%
Risk Analysis for FESS Materi... 0%
Quality Assurance for Optimiz... 0%
Solid Modeling of the FESS a... 20%
Ordering parts for FESS and VWT... 10%
Manufacturing 3 Prototypes:... 10%
Assembling the manufacture... 20%
Testing FESS Prototype with... 20%
Publication of Article: Review of... 10%
Testing of FESS/VWT for Energy... 10%
Testing the VWT Prototype with... 0%
Publication of Article: Academic P... 10%
Publication of Article: Energy... 20%
Publication of Article: Bearing... 10%
Writing up the PhD Thesis 30%
Thesis Examination & Defence 0%
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Publication of Article: Review of public...
Testing of FESS/VWT for Energy Efficienc...
Testing the VWT Prototype with wooden bl...
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