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Modeling the powertrain of a low-cost tractor using sysml language.

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Abstract- The objective of this work is the characterization of the powertrain of a tractor named low-cost using the sysml language. This characterization is divided into three approaches: functional, structural and behavioral. In the functional approach, the functional requirements that must be fulfilled by the system are defined by a requirement diagram. The structural approach is implemented by a presentation of the main components of the system by the block definition diagram and an inter-structural description of the system by the internal block diagram. Finally, a behavioral description is realized by the state diagram.

Keywords— **tractor, hybrid, structural approach, behavioural approach, functional approach**

I. INTRODUCTION

Feeding 10 billion people worldwide makes agriculture the most important industry [1]. In this industry, the tractor is the most widely used machine. Its role is to support the tools and agricultural equipment installed [2]. Conventional agricultural tractors are equipped with internal combustion engines. Like all other modes of road transport, the principal kind of associated pollution with the use of tractors is air pollution, linked to combustion gases containing polluting substances and released into the atmosphere [3]. These emissions have adverse effects at several levels. First of all, the high impact on the deterioration of air quality by (SO2, NOx, volatile organic co-components called VOCs, CO, particles). Second, global warming by (CO2, CH4, N20, particulate matter) [4]. In addition, the depletion of oil resources becomes the main threat to human beings [5]. The EPA estimates that off-road vehicles contribute at 33% of hydrocarbon (HC) emissions, 9% of carbon monoxide (CO), 9% of nitrogen oxides (NOx) and 2% of particulate emissions in the United States [6]. After the climate conferences (COP21, COP22), which mainly focused on reducing greenhouse gases contributing to global warming, the majority of manufacturers are turning to hybrid vehicles, setting the objective of a future clean environment. There is still an evident lack of hybrid and fully electric technology in the agricultural machinery sector [7], where the principle of this motorisation is to operate two engines according to the driving need. The overall objective of this architecture is to combine the advantages of both drive modes [8] [9]. The automotive industry has already started to move towards the construction of green vehicles. This approach focuses mainly on the three areas of emissions, noise and fuel consumption. The aim is to significantly reduce vehicle emissions and increase fuel economy, which is beneficial for environment [10]. Understanding the disadvantages of conventional tractors has been a challenge in thinking about LOW-COST tractors. The latter will provide an economical and efficient solution to the customer's needs.

The low-cost tractor will be described according to a functional, structural and behavioural approach using the sysml language.

II. SYSML LANGUAGE DEFINITION

SysML is a modeling language defined by the OMG, seen as an extension of UML. It is intended for graphical modeling of complex systems. There are three types of diagrams: functional, structural and behavioral. Figure 1 describes the different types of sysml diagrams. Moreover, it defines those that are identical, modified and added to those of the UML. The Systems engineers have long used modeling techniques such as SADT and SA/RT, dating back to the 1980s. We decided to use the SysML language for different reasons. First of all, the SysML language is very recent and growing, and it is used more and more in many high-ranking companies today. Second, a SysML model provides more usable information than other types of models. With information on structure and dynamics, there is therefore more possibilities to arrive at a conclusive fault diagnosis where one is stuck due to lack of usable information with the models used so far [11].

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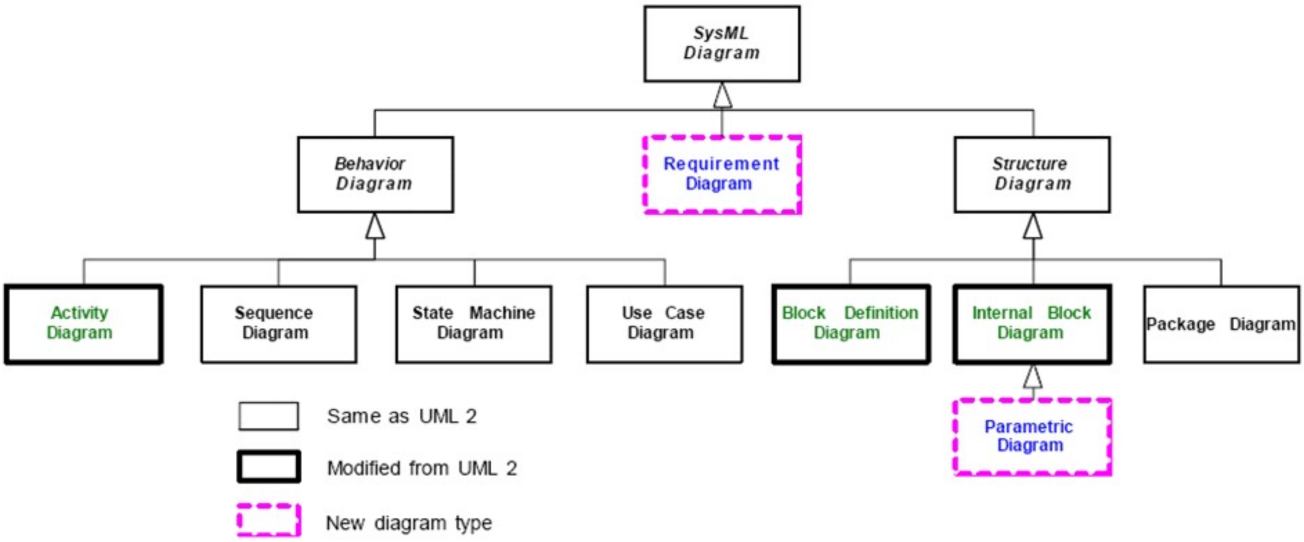

Fig.1 The nine diagrams according to the four pillars of modeling in the SysML language

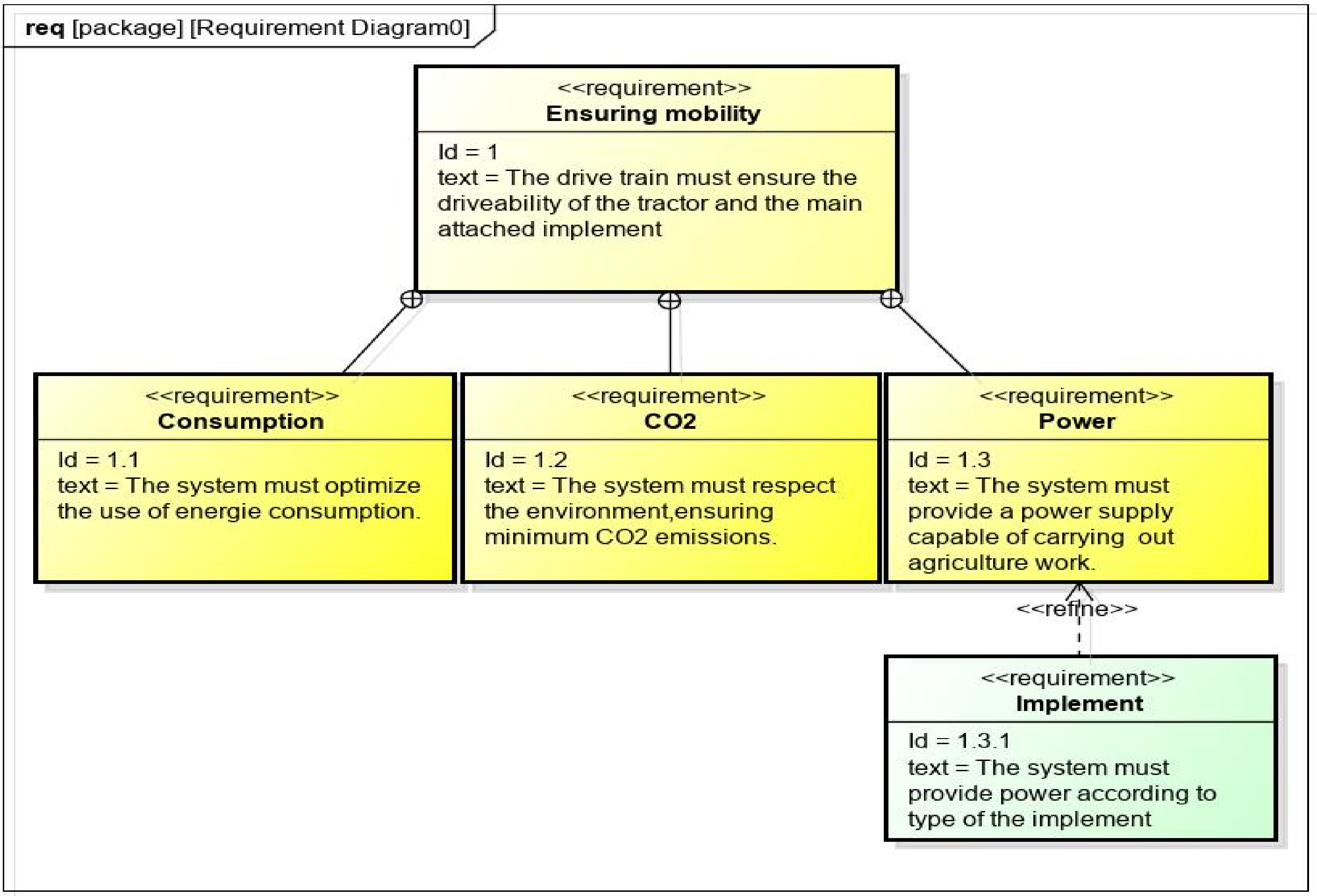

Fig. 2 Requirement diagram of the drive train of the low-cost tractor.

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III. SYSTEM MODELING

In this part, we will project the sysml language that is generated on our system. This projection will be divided into 3 parts.

A. functional description:

The functional description will be carried out, using the requirements diagram. The requirement diagram is a functional diagram that describes the requirements of the functional specification. Each requirement expresses a capability or constraint to be satisfied by the system. A requirement may express a function to be performed by the system or a condition of technical performance, physical, reliability, safety, ergonomics, aesthetics.

Figure 2 shows the powertrain requirements diagram for the low-cost tractor. As it is simulated here, the system must provide enough power working it able to ensur the driveability of the tractor, while emitting a minimum of CO_2 and a very low consumption compared to conventional engines. By fulfilling these requirements, the low-cost tractor can be considered a green vehicle.

B. *structure choice:*

The engine of the low-cost tractor is of parallel hybrid architecture. The latter is equipped with an electric traction motor that drives the wheels and can recover part of the braking energy in order to charge the batteries (regenerative braking) or to help the internal combustion engine during acceleration. There are several configurations of the mechanical device of the combination depending on the structure between the internal combustion engine and the electric motor. There can be a coupling with a single shaft or twin shaft configuration, a speed coupling with a planetary gearbox, a merger of the two previous couplings [12] [13].

The choice of the hybrid structure is based on a study, which has already been carried out. This study approved that the optimal structure for the low-cost tractor is the hybrid one. The latter will provide the necessary power for each implement. And the same time, it will guarantee a very low consumption cost compared to the electric motorization and a low emission compared to the thermal one. The table 1 summarizes some of the results obtained [14].

TABLE I
COMPARISON TABLE

Name of Implement		**Moldboard Plow**	**Bette harvest**	**Flail Mower**
Diesel Fuel Internal Combustion	**Consumption in Cost Terms** (€)	9.04	11.06	16.47
	CO2 Emission (Kg/H)	23.80	29.15	43.40
Engine Electrical Engine	**Consumption in Cost Terms** (€)	18612.72	22780.8	33909.12
	CO2 Emission (Kg/H)	0	0	0
Proposed Hybrid System	**Consumption in Cost Terms** (€)	6.78	8.29	12.35
	CO2 Emission (Kg/H)	17.85	21.86	32.55

C. *Structural description*

The structural description will be made using the block definition diagram and the internal block diagram. The block definition diagram is the basis for modeling the system architecture. It represents the elements constituting a system or subsystem, by aligning the constituents in form of blocks according to their hierarchy and their classification in the overall system. Figure 3 shows the block definition diagram of our system, which aligns the components of the resulting hybrid structure.

The Block Diagram presents an inter-structural description of the system, representing the individual components by blocks with connection ports. It also specifies the different internal flows (Material, Energy and information...) exchanged between the blocks.

Figure 4 shows the internal block diagram of our system, showing the different components and the exchange flows between them.

D. Behavioural Description:

The behavioral description will be performed, using StateMachin Diagram. The latter is a dynamic diagram. It shows the different successive states and the possible transitions of the dynamic blocks. It represents the succession of states of a system or subsystem. The dynamics of change are maintained by events. The figure 5 shows the StateMachin Diagram of our system. It illustrates the different states in which the electric motor and internal combustion engine intervene to supply energy.

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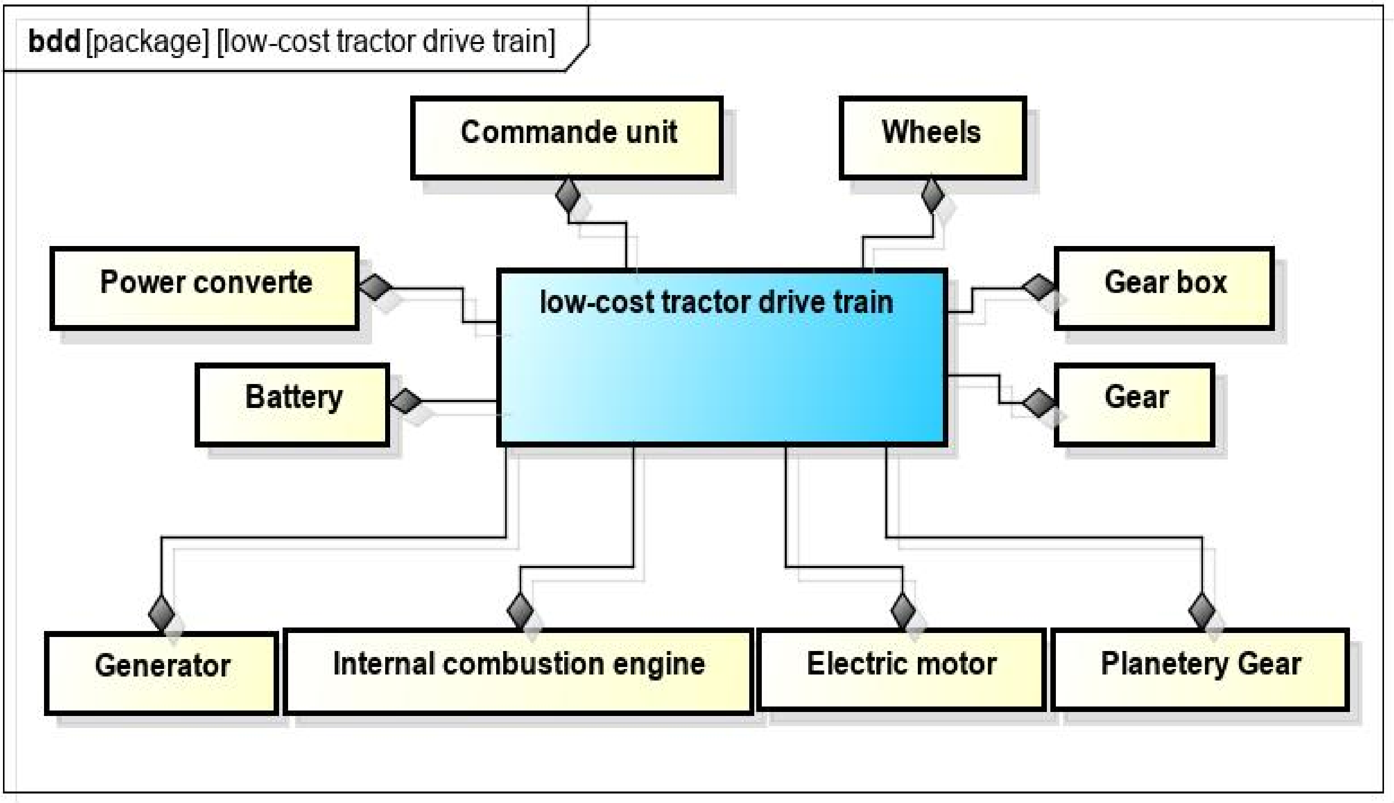

Fig. 3 Block definition diagram of the drive train of the low-cost tractor.

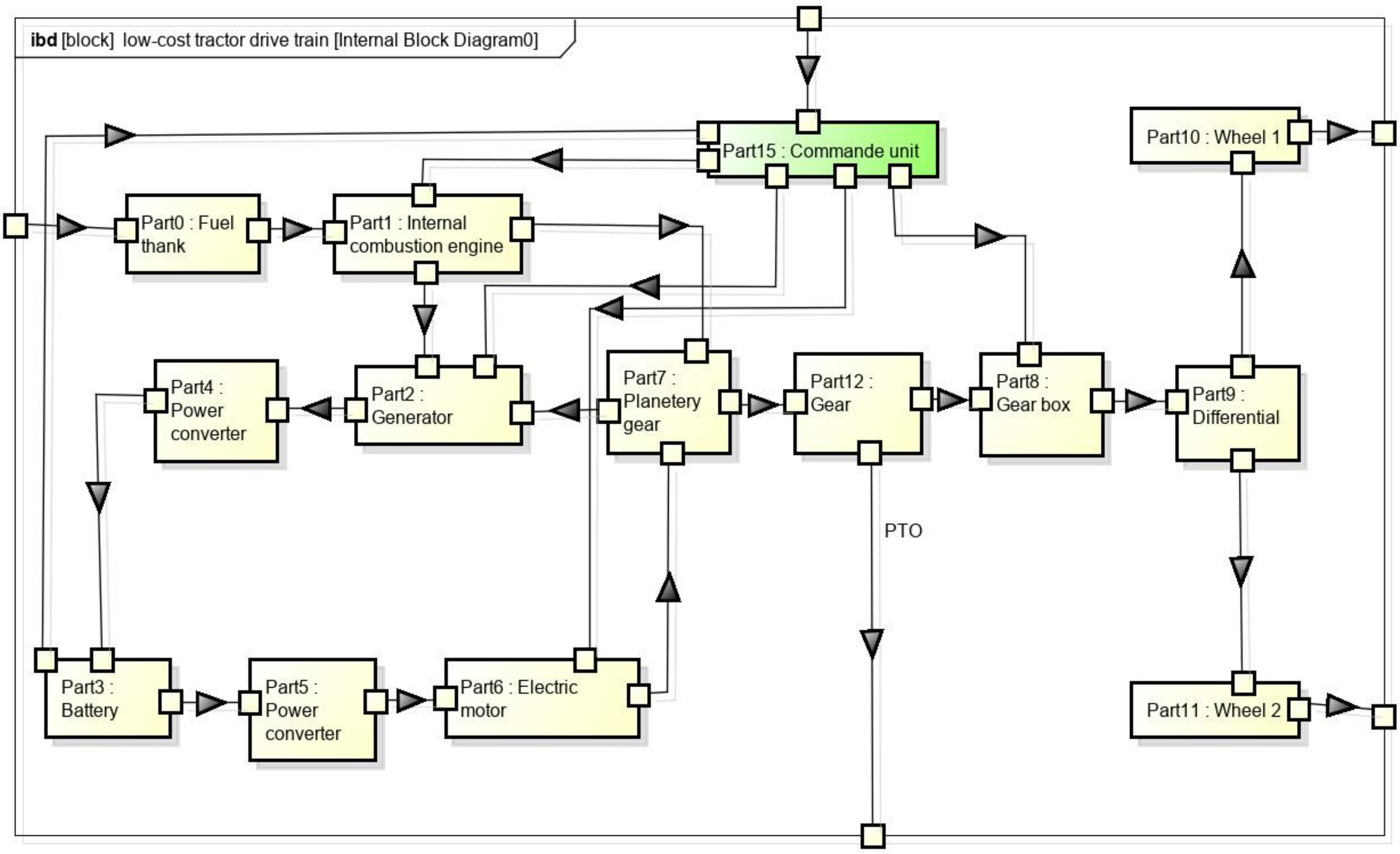

Fig. 4 Internal block diagram of the drive train of the low-cost tractor.

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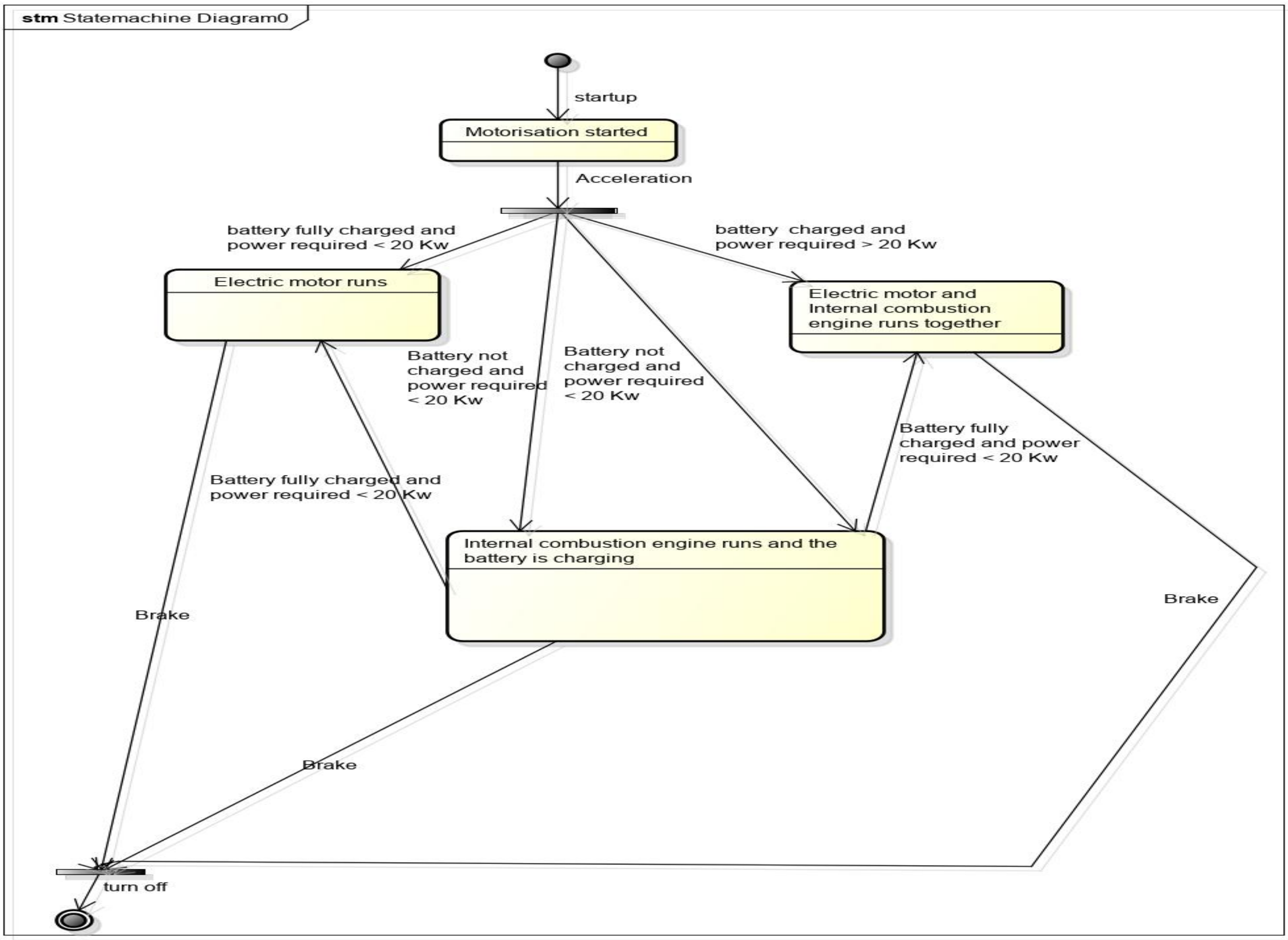

Fig. 5 StateMachin Diagram of the drive train of the low-cost tractor.

IV. CONCLUSION

The systems engineering approach adopted in this study allowed the system to be described using a functional, structural and behavioural approach in the form of graphs (SysML diagrams). The requirements diagram allowed us to present the different requirements to be fulfilled by the system. The structural approach will be illustrated by the block definition diagram and the internal block diagram. The functioning of the system is illustrated by the state diagram. The next studies will be dedicated to the integration of renewable energies in the powertrain of a so-called low-cost tractor.

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